Predatory Information Sales*

Samuel Lee†
Stockholm School of Economics & SITE

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Abstract

When investors must specialize in certain information, the sale of information can reduce information diversity in financial markets. Improved access to one type of information initially decreases market liquidity, thereby depreciating the value of another type. Exploiting this externality, a monopolist may sell information just cheaply enough to preempt the production of non-marketable information. Competition among information sellers can mitigate this problem by further popularizing sold information. This improves market liquidity and thus the incentives to search for additional information. The benefits of competition are less pronounced when communication technologies are inefficient or entry barriers are high. Thus, countries that are technologically advanced and have less regulated information markets should have more diversely informed investors and more informative stock prices. This can induce cross-country differences in stock price comovement.

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†Stockholm School of Economics, Box 6501, 113 83 Stockholm, Sweden, samuel.lee@hhs.se.

1 Introduction

The rise of modern information and communications technologies and of the mass media have reshaped the way societies generate and process information. According to Peter Drucker, the changes have been so profound that "almost everybody today believes that nothing in economic history has ever moved as fast as, or had a greater impact than, the Information Revolution."

While the benefits are ubiquitous, the developments also create new concerns. A recurrent criticism is that the reliance on mass media reduces pluralism, in particular when ownership of media is concentrated (Diller, 2003).[1] For instance, recent research suggests that concentrated media are more prone to political bias or capture (Besley and Prat, 2005; Djankov et al., 2003). Similar views have also been a central tenet in US media regulation (Horwitz, 2004).

In this paper, I explore another channel through which commercial information sales can reduce diversity of opinion: by crowding out privately generated information. This effect can arise even if the information provider has no agenda apart from maximing her own profit, making it relevant not only for the sociopolitical sphere but for any situation in which information has value. In fact, information services are likely to emerge wherever people search for information to improve their decisions (Stigler, 1961). Understanding the impact of these services on private information production is therefore important for understanding ultimate decision-making and outcomes.

I explore this issue in a financial market setting. Financial markets seem ideally suited for this analysis. First, the value of information is obvious: It increases the value of investment decisions, which leads to a well-defined demand function. Second, in practice, this information demand spurs a multi-billion financial information industry, specialized in selling economic and business data. Third, investors can and may want to produce proprietary information, in particular because not all kinds of information are marketable. While the focus on financial markets is illustrative, the main arguments can be applied to other situations in which agents use information to compete over scarce goods (e.g., investment profits).

The paper's main result is that the impact of information sales on the diversity of investor beliefs depends on the degree of competition in the information market. At one extreme, a monopolist engages in predatory pricing: If possible, she sets the price just low enough to preempt private information production, and otherwise she sets it as high as possible. This is because other information sources reduce the value of her product by capturing a fraction of the ensuing investment profits. At the other extreme,

[1]In his speech to the US National Association of Broadcasters, Barry Diller, former head of the Fox Network, critisizes the lack of diversity in the US media industry: "Are we going to get diversity? Conglomerates buy eyeballs... that's it. They leverage their producing power to drive content, their distribution power to drive new services and their promotional power to literally obliterate competitors."

Bertrand competition reduces the price to the second most efficient seller's break-even price, thereby popularizing sold information. When sold information is sufficiently mainstream, investors increasingly tap private sources of information. In short, a competitive information market is less likely to homogenize market beliefs.

As a result, information sales have important consequences for financial market prices. Prices aggregate and reflect traders' information and, as such, can resolve uncertainty about the underlying assets (price informativeness), or reduce investors' losses to better informed parties (market efficiency).[2] Relative to the absence of information markets, predatory information sales affect these dimensions in different ways. The reason is that, while more investors become informed, they acquire more similar information. This intensifies competition among informed traders, which increases market efficiency. However, the loss in diversity can reduce the total amount of information impounded in the price, that is, price informativeness. By contrast, competition makes prices more informative, as it both increases the investor base and fosters diversity.

Finally, I examine the determinants of information market competition. Information production and distribution typically requires significant irreversible investments, which is conducive to natural monopoly (Baumol, 1982). Set against this background, competition is best viewed (or modelled) as market contestability. In my model, technological innovation and low entry costs increase the threat of entry by a more efficient seller. This promotes information diversity by limiting the incumbent's price-setting power. Based on this result, I provide a novel explanation for why stock price comovement (a) is higher in emerging economies and (b) has overall declined in the last decades: These patterns may reflect differences in information market competition and entry regulation, as well as the evolution of information and communication technologies during the 20th century.

The model consists of an asset market and an information market. The stochastic asset value is driven by a set of unobserved fundamentals. Investors can attain data about each fundamental at some cost. However, limited information capacity forces every investor to specialize on a subset of fundamentals. Importantly, not all data is marketable, making some fundamentals discernible only through private enquiry.

The asset market is organized by a market-maker, who represents the counterparty to each trade. Information is traded by means of subscriptions. A subscription obliges the seller to provide the buyer with a particular type of information at a specified future date. Information is marketable if the seller can guarantee its truthful provision. Events unfold as follows: Information sellers post prices at which investors can subscribe to the delivery of marketable data; investors choose, if any, between marketable and (privately generated) non-marketable data; and, finally, informed investors trade in the asset market

[2] Hayek (1945) describes the importance of markets and prices for aggregating dispersed information. This notion has been formalized, among others, by Grossman (1976), Hellwig (1980) and Diamond and Verrecchia (1981) for rational expectations equilibria, Vives (1984, 1988) for oligopolistic markets, and Wilson (1977) and Milgrom (1979, 1981) for auction settings. This paper considers a dealer market.

to earn profits.

Key to the results in this paper is a liquidity externality among traders in the asset market. When there are many informed traders, the order flow contains more information. This can make the price more sensitive to the order flow, that is, the market less liquid. This in turn limits how much informed investors can capitalize on their superior knowledge. In the model, this effect is captured by the market-maker's price-setting behavior. Given that some traders are better informed, she draws inferences from order imbalances to adjust the price accordingly (Kyle, 1985; Glosten and Milgrom, 1985). The rate at which the price adjusts depends on the amount of information impounded in the order flow, which is determined by the population (number and types) of informed traders. Thus, every investor affects the terms of trade of all investors, including those who trade on different information.

Importantly, the number of traders with similar information has a non-monotonic effect on market liquidity. This results from two opposing effects. On the one hand, a higher number of traders with similar information makes the order flow more informative, which decreases liquidity. Since the potential gain in informativeness is limited, this effect gradually diminishes. On the other hand, a higher number of traders with similar information tend to submit a larger cumulative order. Ceteris paribus, the market maker thus observes a larger fluctuation in the order flow for any given realization of the fundamentals. Therefore, she needs to make a smaller adjustment in the price (relative to the observed order imbalance) to make it reflect the underlying information. As this effect persists, market liquidity first decreases and then increases.

In equilibrium, free entry ensures that expected profits are equalized across different information types. Without information sales, information production choices reflect the relative cost structure of the different information types. Due to competition, it is not necessarily the case that only the cheapest type of information is produced. Similarly informed investors tend to trade in the same direction, thereby revealing more of their joint information to the market maker. As a result, their individual profits are lower. Investors therefore place more value on scarcer information, which creates a natural tendency towards information diversity. However, more expensive information attracts fewer traders, since the higher cost must be met by higher expected trading profits.

While information sellers attract no buyers at prices above the cost of production, they may be able to offer a lower price: Sellers can spread their fixed production and distribution costs over many buyers, and the cost of duplicating information is negligible. However, these fixed costs limit the entry of sellers. Thus, one important question is whether a monopolist is willing, rather than able, to offer a price strictly lower than the cost of production. It is well-known that this is not the case when all information is marketable (Admati and Pfleiderer, 1988). Broadening the investor base intensifies investor competition, thereby depressing overall speculative profits. This is ultimately at the expense of the monopolist, who as the sole provider of information extracts all gains.

By contrast, a monopolist in the present model voluntarily lowers her price if she can thereby crowd out privately generated information. This is possible when an increase in the number of buyers causes liquidity to decrease. Since this lowers the profits of privately informed traders, some of them drop out of the market. This in turn increases the profit of each information buyer, and hence the demand for sold information. In the end, aggregate speculative profits fall, but a larger fraction accrues to the monopolist. It is noteworthy that the monopolist impairs private information production by affecting liquidity, rather than competition, in the asset market. The key is that she exerts control over market liquidity through the supply of sold information.

Compared to the absence of information markets, such predatory information sales have two main effects: The investor base grows, but information becomes less diverse. That is, there are more informed traders, and these traders possess more similar information. Since both effects intensify competition, more of the traders' information is revealed in the price. Thus, market efficiency increases. However, this does not imply that price is overall more informative, that is, a better predictor of the true asset value. Predatory information sales make the order flow more informative about some fundamentals, but less about others. Since a trader's marginal contribution to informativeness increases in the scarcity of her information, a larger but more homogenous investor base does not necessarily increase price informativeness. This result contrasts with the common view that prices become more informative when information becomes cheaper (Verrecchia, 1982).

Competition limits pricing power, and hence information sellers' control over market liquidity. Due to fixed and entry costs, there is still only one seller in equilibrium. However, her price cannot exceed the break-even price of her closest competitor. When this constraint is binding, the equilibrium price is lower than under pure monopoly. The larger the price reduction, the more contestable the monopoly. If competition makes sold information sufficiently cheap, and hence widespread, market liquidity improves due to the non-monotonicity described above. This in turn increases incentives to produce private information. Countries with more competitive information markets should thus have more diversely informed investors and more informative stock prices, which may explain cross-country differences in stock price comovement.

To the best of my knowledge, this paper is the first to analyze the interaction between information markets and private information production, as well as the impact of information sales on information diversity. Starting with Grossman and Stiglitz (1980), Hellwig (1982) and Verrecchia (1982), one strand of the literature that analyzes information acquisition assumes an exogenously given cost (or price) schedule. In contrast, the literature on information sales, initiated by a series of papers by Admati and Pfleiderer (1986, 1988, 1990), focuses only on sold information and abstracts from other, private sources of information.[3]

The most closely related papers are Subrahmanyam and Titman (1999), Fishman and Hagerty (1995) and Veldkamp (2006a,b), albeit for different reasons. With Subrahmanyam and Titman, my model shares the central feature that the asset value comprises two components, each driven by a different fundamental factor. In their paper, endogenous information acquisition is restricted to information about one of the fundamentals, whereas information about the other fundamental is endowed by nature. I extend their framework by allowing each agent to choose between either type of information, and by introducing an information market. Fishman and Hagerty analyze the decision whether to sell or to trade on information. Like my monopolist, the information seller in their model reduces overall trading profits but captures a larger fraction of it. However, they consider only a single type of information, and it is endowed by nature; that is, agents cannot (choose to) privately generate information. Therefore, issues such as information diversity or crowding out do not arise, and information sales always increase price informativeness. Finally, Veldkamp introduces different types of information. She focuses on the property that information production entails high fixed but low marginal costs, which implies that the (competitive) price of a given type of information is decreasing in its demand. Common to our approaches is that agents may "herd" on a subset of the available information, but the mechanism is different. Specifically, the liquidity externality, which plays a central role in my analysis, does not arise in Veldkamp's rational expectations equilibrium (REE), where agents can condition their trades on the equilibrium price.[4] This difference allows me to derive novel insights regarding the impact of information sales on liquidity-dependent asset markets; that is, markets in which liquidity is provided by uninformed agents, and their willingness to provide liquidity depends on the degree of asymmetric information. In particular, I can compare how monopoly and competition (in the information market) affect information diversity.[5]

The paper is organized as follows. Section 2 outlines the asset market model and derives the trading equilibrium for a given information structure. Section 3 endogenizes information production in the absence of an information market, and shows that one type of information can crowd out another. Section 4 introduces an information market, and examines the pricing strategies of a pure monopolist and of Bertrand competitors. Section 5 discusses the impact of predatory information sales on the information efficiency of the asset market. Section 6 introduces a second asset and endogenizes information market competition to explain cross-country differences in stock price comovement. Concluding

[3] This categorization is not applicable to the general equilibrium framework of Allen (1986a,b), where agents are each endowed with private information that they can either retain or trade with each other.

[4] A problem of REE models is that they give no explanation as to how the price aggregates information (Milgrom, 1981; Pesendorfer and Swinkels, 2000), in particular when agents' behavior should depend only on private information (and not on the information contained in the equilibrium price).

[5] Simonov (1999) is the only other paper, which I am aware of, that compares the impact of these two competitive settings on asset markets. Unlike this paper, he focuses on seller collusion.

remarks are in Section 7, and the mathematical proofs are in the Appendix.

2 Diverse Information and Speculative Trading

I build on the framework of Subrahmanyam and Titman (1999) which offers a tractable analysis of speculation involving strategic traders with different types of information. Consider a single security with liquidation value $\tilde{V} = \tilde{V}_A + \tilde{V}_B$, where $\Theta = \{A, B\}$ is a set of fundamental factors that drive the liquidation value. Let $\tilde{V}_A$ and $\tilde{V}_B$ be independently and normally distributed with mean 0 and variance σ^2. Stochastic independence accentuates the qualitative results, which also hold under imperfect correlation. At the outset, nature chooses the realizations $\tilde{V}_A = V_A$ and $\tilde{V}_B = V_B$.

In stage 1, a finite number of agents each receive data about either factor A or factor B. From this data, they extract information about $\tilde{V}$ in the form of a signal, $\tilde{s}_{i\theta} \equiv V_\theta + \tilde{\epsilon}_{i\theta}$, where $i\theta$ denotes the ith agent endowed with θ-data. Each signal is perturbed by an independent and normally distributed signal error, $\tilde{\epsilon}_{i\theta}$, with mean 0 and variance σ^2_ϵ. These errors represent individual biases in interpreting the data. The overall information structure is summarized by a pair (n_A, n_B), where n_θ denotes the number of agents with θ-data and $n_A + n_B = n$. That is, traders belong to one of two groups specialized in a certain type of information. In addition, individual biases induce heterogeneous beliefs within each group. The information structure and the probability distributions are common knowledge.

In stage 2, the security is traded. Trading proceeds as in Kyle (1985): Informed agents and liquidity traders place orders with a competitive market maker. Order submission is non-cooperative, simultaneous and anonymous. Liquidity traders' aggregate demand $\tilde{y}$ is normally distributed with mean 0 and variance σ^2_y. After receiving all orders in a batch, the market-maker sets a uniform price at which she meets each order.[6]

In stage 3, V becomes publicly known, and the security is liquidated. Yet, crucially, V_A and V_B are not revealed separately, thus precluding individual markets for A and B. All agents are risk-neutral and there is no discounting.

Following the literature, I restrict attention to linear and symmetric strategies. That is, an informed trader's order $x_{i\theta}$ is a linear function of her signal, $x_{i\theta} \equiv \alpha_{i\theta} s_{i\theta}$, and every θ-trader follows the same strategy, $\alpha_{i\theta} = \alpha_\theta$ for all i and θ. Similarly, the market-maker's price is given by $p = \lambda z$, where $\tilde{z} \equiv \sum_\Theta \sum_1^{n_\theta} x_\theta(\tilde{s}_{i\theta}) + \tilde{y}$ is the total order flow. I refer to α_θ as group θ's trading intensity and to λ (λ^{-1}) as price impact (market liquidity).

[6] The main insight of this paper (that information sales can reduce information diversity) also holds when trades arrive sequentially as in Glosten and Milgrom (1985), or liquidity is provided through a limit order book as in Glosten (1994). The common feature crucial for the result is that more informed traders (can) decrease market liquidity. Other results, in particular regarding the effects of information market competition, do depend on specific features of the batch trading model.

I begin with the market maker's price-setting decision. Though unable to observe the motivation behind individual trades, she knows that some of them are based on private information. Therefore, she uses the order flow to make an inference about $\tilde{V}$, and she sets the price so that in equilibrium $p = \lambda z = \mathrm{E}(\tilde{V}\,|z)$ for all z. Due to the normality of $\tilde{z}$, the second equality is equivalent to $\lambda = \mathrm{Cov}(\tilde{V}, \tilde{z})/\mathrm{Var}\,(\tilde{z})$.[7] The ratio measures to what extent variation in $\tilde{z}$ is attributable to variations in $\tilde{V}$ as opposed to variations in $\tilde{y}$ or $\tilde{\epsilon}_i$. The more information the market maker believes to be impounded in the order flow, the greater is the price impact. After substituting for $\tilde{z}$,

$$\lambda = \frac{(n_A\alpha_A + n_B\alpha_B)\,\sigma^2}{\alpha_A^2\,(n_A^2\sigma^2 + n_A\sigma_\epsilon^2) + \alpha_B^2\,(n_B^2\sigma^2 + n_B\sigma_\epsilon^2) + \sigma_y^2}, \tag{1}$$

which shows that the price impact depends on the information structure and (the market maker's beliefs about) the trading intensities. Thus, the market maker's response is based on the latency of trades by either informed group.

I now turn to the informed traders. Trader $i\theta$ chooses $x_{i\theta}$ to maximize $\mathrm{E}(\tilde{V} - \tilde{p}\,|s_{i\theta})x_{i\theta}$, where the expectation is taken over the liquidation value and the yet unknown price. She exploits the expected difference between the two by taking, for example, a long position when $\mathrm{E}(\tilde{V} - \tilde{p}\,|s_{i\theta}) > 0$. In doing so, she transmits information to the market maker, which in turn moves the price against her. To see this, substitute $\tilde{p} = \lambda\tilde{z}$ and the definition of $\tilde{z}$ to rewrite, say, iA's maximization problem as

$$\max_{x_{iA}} \left[\mathrm{E}(\tilde{V}\,|s_{iA}) - \lambda \left(x_{iA} + \sum_{1,\theta\neq i}^{n_A} \alpha_A \mathrm{E}(\tilde{s}_{jA}\,|s_{iA}) + \sum_{1}^{n_B} \alpha_B \mathrm{E}(\tilde{s}_{jB}\,|s_{iA}) \right) \right] x_{iA}. \tag{2}$$

In addition, (2) shows that iA takes into account that other market participants affect the price. Not only must she form conjectures about trading intensities (α_A, α_B) and about the price impact (λ), but she must forecast the signals that others have received (Foster and Viswanathan, 1996). Her signal reveals information about other A-signals, as they are driven by the same fundamentals. Since the signals are positively correlated, she expects other A-traders to trade in the same direction. By contrast, she learns nothing about B-signals, as $\mathrm{E}(\tilde{s}_{jB}\,|s_{iA}) = \mathrm{E}(\tilde{s}_{jB})$, and hence cannot improve her forecast about the direction of B-trades.

Using the Projection Theorem in (2), solving the problem, and using the solution in $x_{i\theta} = \alpha_\theta s_{i\theta}$ leads to the following equations:

$$\alpha_\theta = \frac{\sigma^2}{\lambda\,[(n_\theta + 1)\sigma^2 + 2\sigma_\epsilon^2]}, \qquad \theta \in \Theta. \tag{3}$$

Both (1) and (3) are consistent with individual rationality and Bayesian expectations

[7]By the Projection Theorem, $\mathrm{E}\,(\tilde{a}|\,b) = \mathrm{E}\,(\tilde{a}) + \frac{\mathrm{Cov}(\tilde{a},\tilde{b})}{\mathrm{Var}(\tilde{b})}(b - \mathrm{E}(\tilde{b}))$ when $\tilde{a}$ and $\tilde{b}$ are normal.

for any set of (possibly heterogeneous) beliefs about α_A, α_B and λ. To constitute a Perfect Bayesian Equilibrium, the latter beliefs must coincide with actual behavior. That is, (1) and (3) must hold simultaneously. Solving this system for λ yields two solutions, of which only the positive one satisfies the second-order condition of (2). The equilibrium is a special case of that derived in Subrahmanyam and Titman (1999). All proofs are relegated to the Appendix.

Proposition 1 (Trade Equilibrium) *The trade equilibrium is given by*

$$\lambda^* = \frac{\sigma^2}{\sigma_y}\left[\sum\nolimits_\Theta T(n_\theta)\right]^{\frac{1}{2}} \qquad \text{and} \qquad \alpha_\theta^* = \frac{\sigma_y}{\lambda^*\left[(n_\theta+1)\sigma^2+2\sigma_\epsilon^2\right]} \tag{4}$$

where

$$T(n_\theta) \equiv \frac{n_\theta\left(\sigma^2+\sigma_\epsilon^2\right)}{\left[(n_\theta+1)\sigma^2+2\sigma_\epsilon^2\right]^2}, \qquad \theta\in\Theta. \tag{5}$$

The subsequent analysis is primarily concerned with changes in the information structure. Key to this analysis are two important externalities, which I characterize in the following corollaries. These externalities arise because each trader, even if only by being present, affects the price and hence everyone's terms of trade.

Corollary 1 (Competition Externality) *Trading intensity is lower in the larger group.*

This follows from (4) which implies $n_\theta > n_{\theta'} \Leftrightarrow \alpha_\theta^* < \alpha_{\theta'}^*$. Since traders that observe the same data form similar expectations, their trades tend to reinforce each other's impact on the price. In anticipation, each of them trades more cautiously, thereby curbing their collective impact for fear of revealing too much information as a group. As more traders share the same data, their individual portion of the trading volume falls. In comparison, a trader with rarer data trades more intensively.

Apart from this intragroup externality, there exists an intergroup externality which operates through market liquidity. Group θ's presence lowers market liquidity via $T(n_\theta)$, since the market maker suspects that its members have observed valuable information. Putting it differently, the market maker responds more sensitively to order flow than she would in the group's absence. Crucially, this affects not only group θ but also the other group. The root cause of this externality is that $\tilde{V}_A$ and $\tilde{V}_B$ are bundled and traded at a composite price. A group's impact on market liquidity is non-monotonic in its size.

Corollary 2 (Liquidity Externality) *$T(n_\theta)$ has a unique interior maximum in $\mathbb{R}^+$.*

On the one hand, increasing n_θ makes the order flow a more precise signal of $\tilde{V}_\theta$. By the law of large numbers, individual biases are washed out, thereby reducing noise in the order flow. Ceteris paribus, the order flow correlates more strongly with fundamentals, and price impact increases. On the other hand, an increasing number of traders place similar orders. Abstracting from the first effect, this makes the order flow more volatile, since any given realization, V_θ, causes a larger change in z. Conversely, this implies that any given z requires a smaller adjustment in p to reflect the fundamentals. That is, price impact decreases. Overall, information becomes more precise, and more of it is transmitted into the price. Given that the first effect vanishes for $n_\theta \to \infty$, the second effect dominates for groups exceeding a certain threshold size.

3 Information Production

In this section, I endogenize information acquisition and examine which information structure is obtained in equilibrium. Instead of being endowed with data, agents must decide which data, if any, to gather and analyze. Specifically, in stage 0, each agent can choose between remaining uninformed or producing data about either A or B. To produce data about θ, an agent must incur the cost c_θ. For now, there are no information sales.

It is implicitly assumed that agents are boundedly rational in that they can process only a subset of information.[8] Cooperation between agents is impaired, as truthful communication of signals is not contractible. Since neither individual factors nor individual error terms are revealed, misreported signals cannot be detected. Hence, in a cooperation, agents would either shirk or misreport signals to trade privately.[9]

Traders select data to maximize expected profit. Let $\pi_\theta\left(n_\theta, n_{\theta'}\right)$ denote $i\theta$'s expected profit as a function of the information structure. More specifically,

$$\pi_\theta\left(n_\theta, n_{\theta'}\right) \equiv \rho_\theta(n_\theta, n_{\theta'}) - c_\theta$$

where $\rho_\theta(n_\theta, n_{\theta'})$ denotes $i\theta$'s expected *trading* profit.[10]

I focus only on pure strategies. A subgame perfect equilibrium, henceforth information equilibrium, is then defined by Proposition 1 and by an information structure in which (i) no informed agent prefers to have different data or to be uninformed, and (ii) no uninformed agent prefers to be informed. Normalizing the pay-off from being uninformed to 0, free entry therefore implies that

$$\pi_A\left(n_A, n_B\right) = \pi_B\left(n_B, n_A\right) = 0 \qquad \text{(Free entry)}$$

[8] "Limits in processing (receiving, storing, retrieving, transmitting) information" (Williamson, 1981, p.553; Simon, 1957; Kahneman, 1973) can cause agents to optimally neglect information (Sims, 2003, 2006; Gabaix et al., 2006). Several recent papers explore such rational inattention in financial markets, theoretically (e.g., Moscarini, 2004; Peng, 2005; Peng and Xiong, 2006) and empirically (e.g., Huberman, 2001; Huberman and Regev, 2001; Massa and Simonov, 2005; Hong et al., 2007).

[9] In reality, organizations partly overcome such problems but may nevertheless have to specialize. The agents in this model may, for example, be viewed as investment funds with specific styles (e.g., Chan et al., 2002; Barberis and Shleifer, 2003; Goetzmann and Brown, 2003).

[10] Unless noted otherwise, I hereafter ignore integer problems and treat n_θ as a continuous variable.

in equilibrium.

To begin with, I establish three important properties of $\pi_\theta(n_\theta, n_{\theta'})$.

Lemma 1 (Profit Function) *For $n_\theta, n_{\theta'} \geqslant 0$ and $n \geqslant n_\theta$,*

(a) $\pi_\theta(n_\theta, \cdot)$ *decreases in n_θ,*

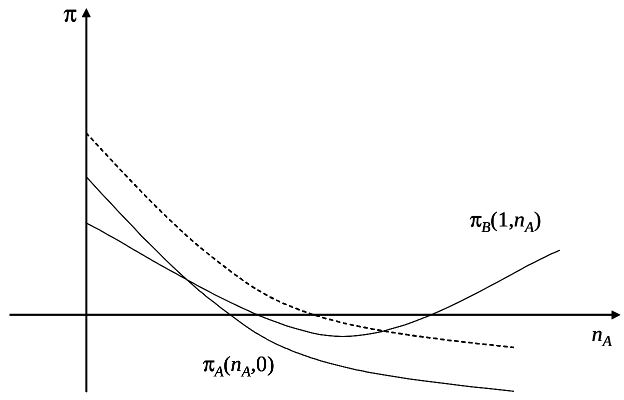
(b) $\pi_\theta(\cdot, n_{\theta'})$ *has a unique minimum in $\mathbb{R}^+$,*

(c) $\pi_\theta(n_\theta, n - n_\theta)$ *decreases in n_θ.*

Intuitively, (a) is a consequence of the intensified competition among θ-traders, which reduces their trading intensity (Corollary 1) and hence their expected profit; whereas (b) results from the non-monotonic liquidity externality exerted by θ'-traders (Corollary 2). Together, the two results describe how expected profits change as new traders enter the market: A new θ-trader not only reduces the expected profit of every θ-trader but may also reduce that of every θ'-trader. These effects are central to the subsequent results.

Given a fixed population, (c) says that a given data type loses value as it becomes more prevalent.[11] This result is due to competition and, at first glance, seems identical to (a). But unlike in (a), increasing n_θ in this case reveals less information to the market-maker when $n_\theta > n/2$ (as I later show in Lemma 4). This creates a tendency for expected profit to increase in group size. However, when a trader switches from θ- to θ'-data, trading intensity both rises in the θ-group and falls in the θ'-group. These adjustments attenuate the impact on price informativeness enough for traders' preferences to be dominated by the competition effect.

This being said, (a) and (b) can serve to develop some intuition for information choices in equilibrium. To this end, let $c_A \leqslant c_B$ and $\pi_\theta(1, 0) > 0$ for $\theta \in \Theta$, and consider first (the graphs of) $\pi_A(n_A, 0)$ and $\pi_B(1, n_A)$ as illustrated in Fig.1. By Lemma 1, $\pi_A(n_A, 0)$ is downward sloping, whereas $\pi_B(1, n_A)$ is U-shaped. Moreover, due to the cost difference, $\pi_A(n_A, 0)$ has a higher intercept than $\pi_B(1, n_A)$. Thus, they intersect (at least) once.



[11] Figlewski (1982) derives a similar result in a Competitive Rational Expectations Equilibrium framework. In either case, the result is a special case of Hellwig and Veldkamp (2007) who show more generally that information choices inherit the strategic motives of the ensuing actions: Agents want to coordinate on different (identical) information when their actions are substitutes (complements).

Fig. 1

Based on this figure, consider the following "sequential" argument. A sole trader prefers A-data to B-data, and the latter to being uninformed. Suppose she chooses A-data. This reduces the expected profit that an additional trader can make from either data type. Still, a second trader confronts the trade-off that B-data, while more expensive, comes with less competition. As long as $|c_A - c_B|$ exceeds the difference in trading profits, she – and every subsequent trader – too prefers A-data. However, with more A-traders entering, the liquidity externality on (potential) B-traders reverts towards zero (Corollary 2), whereas the level of competition among A-traders steadily increases (Corollary 1). Thus, eventually, the marginal trader's preferences reverse.[12]

This preference reversal occurs where $\pi_B(1, n_A)$ and $\pi_A(n_A, 0)$ intersect. As proved in the next proposition, this intersection is unique. The intersection by itself does not imply that B-data is produced in equilibrium. For this, the necessary and sufficient condition is that expected profits are positive at the preference reversal. The dotted line in Fig.1 shows a situation where this condition is violated. In this case, A-traders' expected profits reach zero, and the informed trader population stops growing, before the production of B-data becomes desirable.

It can be shown that the above condition is satisfied if and only if the (unique) root of $\pi_A(n_A, 0)$ does not lie between the roots (if there are any) of $\pi_B(1, n_A)$. I first restrict my attention to the interesting case, when $\pi_B(1, n_A)$ indeed becomes negative for some n_A, thereby segmenting the null axis into three regions: $\mathcal{R}_1 = [0, \underline{n}_A)$, $\mathcal{R}_2 = [\underline{n}_A, \overline{n}_A]$ and $\mathcal{R}_3 = (\overline{n}_A, \infty]$, where $\pi_B(1, \underline{n}_A) = \pi_B(1, \overline{n}_A) = 0$. For future reference, I also define n_A^0 by $\pi_A(n_A^0, 0) = 0$. With this notation, I now characterize the equilibrium information structure, which uniquely satisfies the free entry condition. It turns out that the above intuition carries over to the simultaneous-move case.

Proposition 2 (Information Equilibrium) *Suppose $\mathcal{R}_2$ is non-empty. In equilibrium, $(n_A^*, n_B^*) = (n_A^0, 0)$ if and only if $n_A^0 \in \mathcal{R}_2$. Otherwise, there exists a unique pair (n_A^*, n_B^*), with $n_A^* > n_B^* > 0$, which satisfies the free entry condition.*

That more costly information is less valuable, and therefore less widely or not at all acquired, is neither a novel nor a surprising result. More striking is the fact that B-data, despite being valuable to a sole trader, is only produced in $\mathcal{R}_1$ or $\mathcal{R}_3$, that is, when $n_A^0 \in \mathcal{R}_1 \cup \mathcal{R}_3$. This is because bundling $\tilde{V}_A$ and $\tilde{V}_B$ creates externalities that depreciate the value of information. These externalities are most severe when n_A^0 is intermediate, in which case B-data is completely crowded out. This has two main implications. On the one hand, incentives to search for new information are weakened when existing informed

[12] For the sake of argument, this reasoning presumes each trader to act as if she were the last entrant.

traders reduce market liquidity. These incentives may, on the other hand, be restored as extant information becomes increasingly widespread.

A prerequisite for crowding-out is that $\mathcal{R}_2$ is non-empty or, equivalently, that the overall level of a B-trader's expected profit is not too high. Any upward shift in $\pi_B(1, n_A)$ contracts $\mathcal{R}_2$ and hence reduces the likelihood of crowding out. This implies the following intuitive corollary.

Corollary 3 *High exogenous liquidity and cheap B-data promote information diversity.*

I omit the proof which merely shows that $\pi_B(1, n_A)$ increases in σ_y^2 and decreases in c_B. Consistent with intuition, prices of less liquid assets should incorporate less diverse information, and more expensive information is more likely to be crowded out. It should be noted that, for crowding out to be a concern, not all but merely some information must be expensive enough to be affected by the externality. This seems reasonable to assume, in particular since the analysis extends to more than two information types.

Throughout the remainder of the paper, I assume that $\mathcal{R}_2$ is a non-empty set and analyze how changes in the cost of A-data affect the equilibrium information structure. The analysis heavily exploits the following comparative statics result. Let $n_A^0(c_\theta)$ denote the root of $\pi_A(n_A, 0)$ for a given set of cost parameters.

Lemma 2 *$n_A^0(c_\theta)$ is strictly decreasing in $c_\theta \in \mathbb{R}^+$.*

Trivially, a lower cost of θ-data admits more θ-traders. Again, I omit the proof which shows that $\pi_A(n_A, 0)$ decreases in c_θ. The result immediately implies that lowering c_θ moves $n_A^0(c_\theta)$ through the three regions, from $\mathcal{R}_1$ to $\mathcal{R}_3$, thereby having a non-monotonic impact on information diversity. Let $n_A^0(\underline{c}_\theta) = \underline{n}_A$ and $n_A^0(\overline{c}_\theta) = \overline{n}_A$.

Corollary 4 *Crowding out occurs if and only if $c_\theta \in [\underline{c}_\theta, \overline{c}_\theta]$.*

Intermediate costs induce an intermediate group size, $n_A^0(c_\theta) \in \mathcal{R}_2$, which in turn crowds out θ'-traders. Thus, a decrease in the cost of one information type can reduce information diversity, even with an unlimited number of potential traders. The reason is that more informed trading, at least initially, decreases market liquidity.

4 Predatory Information Sales

In practice, many traders subscribe to information sellers that supply economic, business and financial news and data.[13] This section examines how information sellers affect the equilibrium information structure in the present model.

[13] In practice, part of the information market trades not in information about fundamentals, considered here, but in market data such as prices or quotes. The latter is analyzed in Boulatov and Dierker (2007).

I extend the model as follows. In stage -1, each information seller sets a price at which agents can subscribe to the provision of A-data. (I show that this pricing strategy is optimal.) In stage 0, each agent can either remain uninformed, purchase a subscription, or produce data privately. A seller who receives a subscription collects and delivers in stage 1 the promised data to the subscriber. Each information seller has access to a technology through which she communicates the data to her subscribers, and operating it imposes a fixed cost K. The marginal cost of communication is negligible. The information is provided truthfully, and it is so short-lived that it cannot be resold. Finally, information sellers cannot add noise to the data (Admati and Pfleiderer, 1986).

It is important to recognize that not every producable information is marketable. This is reflected in the assumption that B-data cannot be sold. Certain information may be too complex to be communicated without dissipating some content, or it may be too soft (unverifiable) for communication to be credible (Allen, 1990; Michaely and Womack, 1999). These problems can render a direct sale unattractive, or even impossible.[14]

The assumption of high fixed but low marginal costs is also characteristic of information markets. Large scale and timely dissemination of information often requires setting up a communication or distribution network. As a result, information and communications industries are often highly concentrated.[15] In many countries, entry regulations and political capture impose further restrictions on competition. Set against this background, a situation in which an information seller has (some) monopolistic power is by no means implausible. Hence, I consider in turn the case of a monopolist and that of a contestable market (with Bertrand competition).

Before the main analysis, I establish that uniform pricing schemes without quantity restrictions are optimal in this simple model, also relative to indirect sales.[16]

Lemma 3 (Uniform Pricing) *Selling data directly by offering unlimited subscriptions at a single price is optimal.*

To understand the intuition behind this result, consider any price-quantity schedule posted by a monopolist. With free entry, the expected trading profit of each subscriber must equal the highest subscription price paid in equilibrium. This follows directly from

[14] For instance, Goetzmann et al. (2004) find that movie scripts that are less certifiable by hard information are sold at a discount. That is, the scriptwriter incurs a higher cost of selling 'soft' information. (If possible, she might prefer to instead produce the movie herself.) As regards speculative information, Roll (1988, p.564), in his well-known study on stock price comovement, concludes that his results seem "to imply that the financial press misses a great deal of relevant information generated privately."

[15] It is well known that the financial information services industry is dominated by a few large firms. The three largest firms (Bloomberg, Reuters and Thomson) have a combined market share of about two-thirds. Reuters and Thomson have recently agreed to a merger (New York Times, 9 May 2007).

[16] In an indirect sale, the seller sets up an investment fund, and investors can participate in the seller's knowledge by purchasing fund shares. I do not consider pricing schemes, where the subscription fee is contingent on realized trading profits. In the context of direct sales, this question has not been addressed in the literature. This may be because, in practice, the subscriber's use of the data, including any ensuing profit, is difficult to monitor or to verify.

the fact that expected trading profits are symmetric within a group. Hence, at all lower prices, subscribers pay less than their reservation price, and the monopolist would earn more by eliminating those prices. Thus, binding quantity restrictions are suboptimal from the seller's point of view. Slack restrictions are unnecessary.

Indirect sales can serve as a means to control the usage of information, that is, the number of informed traders. This can increase the seller's profit by limiting competition (Admati and Pfleiderer, 1990). However, this benefit does not arise in the present model, as traders can resort to alternative sources of information, namely to self-production or to a competing seller. As an illustration, suppose that a monopolist sets up a fund and sells shares at a fixed price. Since her optimal trading strategy is identical to that of a single trader, $n_A^* - 1$ other traders will enter stage 2 with self-produced A-data. The fund's expected trading profit will be $\rho_A(n_A^*, n_B^*)$, which in turn is the most anyone is willing to pay for its shares. If the monopolist instead supplies the data at $p_A = c_A$, she extracts the expected trading profits of all A-traders, $n_A^* \rho_A(n_A^*, n_B^*)$.

4.1 Uncontested Monopoly

This setting has been extensively analyzed by Admati and Pfleiderer (1986, 1988, 1990). As already pointed out, the present model differs from theirs in that, here, the monopolistic power encompasses only the *sale* but not the *production* of information: Traders can always opt for primary information sources. This has two important consequences. First, the production cost represents an upper bound on the monopolist's price. Second, the monopolist always fares better by (also) selling data than by merely trading on it. This is because she cannot lose from selling it to those that would otherwise collect it privately. For simplicity, I assume that information sellers do not trade.

Let $p_A \in [0, c_A]$ denote the monopoly price. The number of subscriptions, $n_A^*(p_A)$, is endogenously determined as a function of the price. The monopolist chooses p_A to maximize her total profit

$$\Pi(p_A) = \begin{cases} n_A^*(p_A) p_A - c_A - K & \text{if } p_A \leq c_A \\ 0 & \text{if } p_A > c_A \end{cases}. \tag{6}$$

I restrict attention to cases where positive profits are feasible, that is, $\Pi(c_A) > 0$. Provided that $p_A \leqslant c_A$, free entry ensures that subscriptions are sold until the subscribers' expected profits are driven to zero. As a result, A-traders' expected trading profits are fully extracted by the information seller, which allows me to rewrite the profit function as

$$\Pi(p_A) = n_A^*(p_A) \rho(n_A^*(p_A), n_B^*(p_A)) - c_A - K. \tag{7}$$

This expression highlights not only that p_A jointly determines n_A^* and n_B^* but also that maximizing the monopolist's profit is tantamount to maximizing the total trading profits of A-traders.

In (6), the seller's profit looks very similar to that of a standard Cournot monopolist, albeit with zero marginal cost. To build up intuition, consider when the monopolist would gain from marginally reducing the price. Rewriting $\partial\Pi\left(p_A\right)/\partial p_A < 0$ as

$$\left|\frac{\partial n_A^*\left(p_A\right)}{\partial p_A}\right| p_A > n_A^*(p_A)$$

shows that this requires the marginal revenue from the new subscribers to exceed the marginal loss on the existing subscribers. In a standard Cournot model, this may hold, at least for some $p_A \leqslant c_A$, if $n_A^*(p_A)$ is sufficiently steep. If so, the monopolist optimally trades off price against quantity, recognizing that a lower price raises sales and extracts the additional consumers' utility.

However, a monopolist selling information to traders, who in turn compete over speculative profits, faces the problem that buyers reduce each others' valuation of the "good". That is, new subscribers' trading profits come at the expense of existing traders. In fact, due to intensified competition, the former's gain is always smaller than the latter's loss, and total trading profits decrease. If $n = n_A$, this means that the partial derivative of total trading profits in (7) with respect to p_A is positive, and rewriting the inequality yields

$$\left|\frac{\partial n_A^*\left(p_A\right)}{\partial p_A}\right| \rho(n_A^*(p_A), n_B^*(p_A)) < n_A(p_A)\left|\frac{\partial \rho(n_A^*(p_A), n_B^*(p_A))}{\partial p_A}\right|.$$

When lowering the price, the marginal gain from new customers (left-hand side) is always smaller than the marginal loss on old customers (right-hand side). Hence, if all information is purchased from the monopolist, the latter cannibalizes her own profit by expanding the investor base through lower prices (Admati and Pfleiderer, 1988). So, she chooses $p_A = c_A$.

By contrast, the monopolist in the present model may deviate from the corner solution. Suppose $n_A^*(c_A) \in \mathcal{R}_1$. Then some traders choose to collect B-data when $p_A = c_A$. These B-traders impose a negative externality on A-traders, and the expected trading profits of the B-traders do not accrue to the information seller. When lowering the price, the seller reaps the trading gains of all new subscribers. But compared to the case where $n = n_A$, she does not fully internalize the profit decrease of the existing traders if part of that decrease is borne by B-traders. This occurs when additional A-traders decrease market liquidity, thereby crowding some B-traders out of the market. This in turn allows more A-traders to enter, and the monopolist to appropriate a larger fraction of the (lower) total trading profits. While it follows from Corollary 4 that crowding out is possible, the next result shows that this predatory pricing strategy is indeed profitable for the monopolist.

Proposition 3 (Predatory Pricing) *If $n_A^0(c_A) \in \mathcal{R}_1$, the monopolistic seller sets $p_A = p_A^m < c_A$ where $n_A^0(p_A^m) = \underline{n}_A$ with the purpose of preempting the production of B-data.*

The monopolist has no interest in increasing the number of A-traders over and above $\underline{n}_A$, as the sole effect would be to intensify the competition among them. Similarly, she does not gain from lowering the price if $n_A^0(c_A) \notin \mathcal{R}_1$. In $\mathcal{R}_2$, there are no B-traders to begin with; in $\mathcal{R}_3$, additional A-traders would mitigate, rather than exacerbate, the externality on B-traders.

The motivation of the monopolist is similar to that of an information seller in Fishman and Hagerty (1995). There, several agents endowed with the same signal compete over speculative profits, and selling one's signal acts like a commitment to trade more aggressively. In response, competing traders reduce their trading intensity, and the seller captures a larger share of the total trading profits. Here, the seller is not concerned about competing against traders with the same data, since she can induce them to buy the data from her and extract their trading profits. Rather, she is concerned about traders with different data, who exert a negative externality on her subscribers. To reduce the impact of these non-subscribers, the seller goes one step further: Instead of merely curtailing their trading intensity, she forces them out of the market altogether.

4.2 Historical Anecdote: The Birth of Reuters

The following anecdote, taken from Read (1999), illustrates the above arguments. In its early days, Reuters, the British data and news agency, had a competitive edge in distributing information. It had superior knowledge of telegraph networks as well as exclusive access to vital news "channels", such as the right to circulate news received by the Austrian Lloyd's via ships from the East. To develop its business, it offered the main London newspapers subscriptions to its international news dispatches at £30 per month. This was significantly less than a newspaper's cost of running its own correspondent network. At this price, Reuters had to attract a critical number of daily newspapers to make the service profitable, and it succeeded:

> "By accepting the collection of news through Reuters, the rival London newspapers had finally realized that they would be able to receive a much fuller supply of general news and commercial information than they could *each* [emphasis added] collect separately...identical Reuter telegrams were appearing in other newspapers."[17]

Like others, The Times, the most influential British newspaper at the time, initially resented becoming dependent on Reuters and preferred to rely on its own correspondents.

[17] All quotes in this section are taken from Read (1999, p.24).

However, the value of running its own network deteriorated, as its rivals gained improved access to international news:

> "Good though its own network was, [The Times] needed to know each evening what telegrams from Reuter were likely to appear in the columns of its competitors next morning, even though it did not necessarily want to print the telegrams itself."

Succumbing to the competitive pressure, The Times eventually took out a Reuters subscription. Even so, its general manager continued to complain about "charges, delays, or what he claimed to be inadequate coverage". By 1861, the Reuters service had become indispensable, providing the lion's share of foreign news to all major London newspapers. Although the latter were at liberty to maintain their own networks, reducing in-house production was most likely part of their decision to outsource these services. It is important to note that Reuters telegraphs were in nature different from the reports of overseas newspaper correspondents:

> "The Times kept a correspondent at the front, the famous W. H. Russell, who wrote long mailed dispatches. These made a great impression by revealing military shortcomings, but they were not intended to give the latest news."

Clearly, Reuters priced its services such that they would replace the newspapers' own networks. On the one hand, this gave each individual newspaper cheaper access to international news. On the other hand, total coverage became more homogenous. Moreover, the short news dispatches may have crowded out more complex and soft information, such as the in-depth coverage by newspaper correspondents.

4.3 Contested Monopoly

Suppose that sellers enter sequentially and compete in prices à la Bertrand. It is well known that if firms must pay a sunk cost of entry, the unique subgame perfect equilibrium is that only one firm enters. This is because, in the post-entry subgame, competition would drive prices down to the (second lowest) marginal cost, and all or at least some firms would not recoup their sunk cost. Thus, the standard analysis with entry costs predicts a natural monopoly to which the results of the previous section apply.[18]

[18] That sunk entry costs lead to a monopoly is not necessarily true if participation in the competition after entry is stochastic (Janssen and Rasmusen, 2002), entry decisions are made simultaneously (Sharkey and Sibley, 1993; Marquez, 1997), or competitors have private information about their marginal costs (Spulber, 1995). In all these cases, competitors' (expected) post-entry profits are positive. However, these assumptions do not seem characteristic of information markets: Both entry and participation seem rather visible (due to concentration and the importance of marketing), and marginal costs are typically negligible. In Section 6, I develop a more realistic extension with entry costs.

Fixed (distribution) costs also lead to a monopoly, but – unlike entry costs – they do not necessarily entail monopoly pricing. This is because the attempt to undercut the incumbent's price is costless for a challenger: If she fails and hence attracts no demand, she bears no cost. As a result, the incumbent must set the price equal to the break-even price of the most efficient challenger, or surrender the market (Baumol and Willig, 1981). In this sense, the market is competitive even though there is, in the end, only one seller.

To highlight the effect of competition in a relatively simple setting, I first abstract from entry costs and let K denote the fixed distribution cost of a potential entrant. (In Section 6, I discuss a case with entry costs.) Without loss of generality, the incumbent's fixed costs are assumed to be negligible. Hence, as discussed above, only the incumbent ends up selling data in equilibrium. Still, because the subscription market is contestable, the equilibrium price cannot exceed the challenger's break-even price p_A^c defined by

$$\Pi\left(p_A^c\right) = n_A^*(p_A^c)\rho(n_A^*(p_A^c), n_B^*(p_A^c)) - c_A - K = 0.$$

I assume that competition is effective (i.e., that K is sufficiently low) so that $p_A^c < p_A^m < c_A$. To begin with, consider prices $p_A < p_A^m$ such that no trader collects B-data. For $n_B = 0$, the A-traders' total trading profit, and hence the seller's profit, decreases in n_A (as discussed in Section 4.1). Thus, there exists a unique $p_A^0 < p_A^n$ such that

$$n_A^*(p_A^0)\rho(n_A^*(p_A^0), 0) = c_A + K$$

Proposition 4 (Competitive Pricing) *Under Bertrand competition, B-data is not collected if and only if $n_A^*(p_A^0) \in \mathcal{R}_2$, in which case the equilibrium price is $p_A^c = p_A^0$.*

As competition pushes down the price, the population of A-traders grows. At first, this growth crowds out B-traders. However, due to Corollary 2, the externality that A-traders exert on B-traders at some point starts decreasing again, thereby increasing the incentives for collecting B-data. Thus, if the seller's profit does not deteriorate too quickly, and if the fixed costs are not too high, competition will eventually reinvite B-traders. On the contrary, if the seller reaches her break-even point before the externality is sufficiently reduced, which is the case when $n_A^*(p_A^0) \leqslant \overline{n}_A$, the information structure remains lopsided.

Proposition 4 has two straightforward corollaries. First, it requires no proof to see that $n_B^*(p_A^c) \geqslant n_B^*(p_A^n) = 0$, where the inequality is strict in some cases.

Corollary 5 *Competition is more conducive to information diversity than monopoly.*

In addition, $n_A^*(p_A^0)$ increases in σ_y^2 (as in Corollary 3) and decreases in K (as shown in the proof of Proposition 4).

Corollary 6 *Competition is more conducive to information diversity when fixed costs are low and exogenous liquidity is high.*

In conclusion, competition has benefits beyond just making A-data affordable for more traders. By popularizing A-data to the extent that it becomes "mainstream" information, competition improves market liquidity and thereby restores the value of other data. Not surprisingly, the capacity of competition to foster information diversity depends on the efficacy of the communication technology, that is, the cost of operating a communications network. It is interesting to compare this positive liquidity-creating role of competition with the result in Morrison (2004). Morrison considers a single type of information and shows that competition among investors reduces each investor's incentive to improve the precision of her signal (for convex costs). By contrast, I focus on how competition causes information sellers to supply information to more traders, and how competition among these traders in turn enables other traders to profit from different information.

Despite the differences between the competition and the monopoly outcome, the central result is that information sales in either environment can reduce information diversity. Thus, information sales can homogenize investors' beliefs and induce them to make similar trades. The reason is not that they mimic each other, but that they "herd" on the same sold information. When information sellers are prone to focus on aggregate or market-wide data, this effect may increase price comovement (Section 6).

5 Information Efficiency

A key role of prices is to aggregate dispersed information (Hayek, 1945). This section examines how predatory information sales affect this property of prices. The benchmark case for all results in this section is the absence of information markets (Section 3).

The literature distinguishes three approaches to measure the information content of prices: market efficiency, price informativeness and allocative efficiency. A market is more (less) efficient if prices reveal more (less) of the information acquired by traders (Fama, 1970, 1991). By contrast, prices are more informative, the more uncertainty they resolve about the asset value. Compared to market efficiency, price informativeness is concerned with the total, rather than the proportion of extant, information impounded into prices (Chen et al., 2007). Allocative efficiency indicates the extent to which price information helps decision-makers to allocate resources efficiently (Tobin, 1982).[19]

[19] Dow and Gorton (1997) make a similar distinction between market efficiency (which they call price efficiency) and allocative efficiency (which they call economic efficiency), and show that price efficiency need not imply allocative efficiency. I further distinguish price informativeness (which in their framework coincides with price efficiency) and argue that none of the three measures necessarily implies the others.

Since market efficiency measures the information contained in prices relative to that possessed by traders, it can be proxied by the aggregate loss that uninformed (liquidity) traders expect to incur due to the presence of better informed traders.

Proposition 5 *Predatory information sales increase market efficiency.*

This results from the increase in the number of informed traders and the subsequent increase in speculative competition. The intensified competition reveals privately held information more effectively to the market maker, who therefore can set the price closer to the informed traders' forecast. As a result, liquidity traders lose less from their uninformed trading.

It is noteworthy that predatory information sales increase market efficiency in two ways, namely by crowding out one type of information and, at the same time, by distributing the other type to more traders. This suggests that the total amount of information flowing into prices, i.e. price informativeness, may not necessarily increase.

Residual uncertainty about the asset value is measured by the conditional variance

$$\mathrm{Var}(\tilde{V}\,|z\,) = \mathrm{Var}(\tilde{V})(1-\rho_{V,z}^2) = \sigma^2(2 - \mathrm{I}\,(n_A, n_B))$$

where (as shown in the Appendix)

$$\mathrm{I}\,(n_A, n_B) \equiv 2\rho_{V,z}^2 = \sum_{\theta=A,B} \frac{n_\theta \sigma^2}{(n_\theta+1)\sigma^2 + 2\sigma_\epsilon^2}. \tag{8}$$

Since residual uncertainty, $\mathrm{Var}(\tilde{V}\,|z\,)$, decreases in $\mathrm{I}\,(n_A, n_B)$, I will use the latter as a measure of price informativeness. The following result helps to develop some intuition.

Lemma 4 $\partial \mathrm{I}\,(n_\theta, n_{\theta'})\,/\partial n_\theta > 0$ *and* $\partial^2 \mathrm{I}\,(n_\theta, n_{\theta'})\,/\partial n_\theta^2 < 0$.

Price informativeness increases in the prevalence of either type of information. However, the marginal gain is decreasing in the prevalence of a given type of information (as the average interpretation error converges to zero due to the law of large numbers). For a fixed trader population, this immediately implies that prices are most informative under a balanced information structure. Hence, information sales decrease price informativeness to the extent that they skew the information structure. Yet, they also increase the size of the trader population, which may compensate for the increase in skewness. In line with the initial intuition, the overall effect is thus ambiguous.

Proposition 6 *Predatory information sales need not increase price informativeness.*

At first glance, this result seems counterintuitive as it implies that cheaper information can lead to less informative prices. At the most basic level, this follows because neither the information seller nor the traders value price informativeness as such. As a consequence, the information seller does not suffer from reduced information diversity. In fact, she deliberately induces it. The reason why the increase in A-traders – over and above the number of those that would collect B-data in the absence of information sales – may not suffice to offset the loss in diversity is that the intensified competition among A-traders diminishes expected profits, thereby curtailing the number of additional entrants.

Even if prices contain more information in the sense of reducing residual uncertainty, they need not be more informative for decision-makers. According to Dow and Gorton (1997), stock prices play both a retrospective role in evaluating past actions and a prospective role in reflecting the value of investment opportunities.[20] Importantly, this requires that stock prices reflect information that is decision-relevant. This need not always be the case. For the sake of argument, suppose that B-data solely relates to past management effort, whereas A-data solely relates to events outside of management's control. In that case, predatory information sales would undermine the performance-monitoring role of stock prices, even if market efficiency and price informativeness were to increase. Thus, the impact of predatory information sales on allocative efficiency depends on the relation between the different types of data, sold or private, and managerial decisions.

6 Price Comovement and Information Markets

One application of the model provides a possible explanation for cross-country differences in stock price comovement. Price comovement measures the degree to which individual stock prices covary with each other, that is, with the market. If comovement is high, market return has strong explanatory power with respect to individual returns.

In a pioneering study, Roll (1988) reports that the average R^2 in regressions of individual stock returns on the market return is rather low, even after controlling for ex post observable factors such as firm size, industry and public news events. From a more detailed analysis with a mixed distribution model to estimate the implicit arrival of "news", he concludes that much of the idiosyncracy seems to originate from privately generated, and thus unobserved, information. According to this view, idiosyncratic price movements reflect firm-specific information that is impounded into prices through informed trades.

Building on this methodology, Morck et al. (2000) document that price comovement is less pronounced in countries with high per capita gross domestic product (GDP) and

[20] For instance, Holmström and Tirole (1993) argue that stock-based compensation can enhance managerial incentives because speculators collect information about managerial actions, which is reflected in prices. In addition, several papers formalize the idea that managers themselves may extract information from stock prices to improve their investment decisions, for example, whether to continue, expand or modify current firm strategy (e.g., Subrahmanyam and Titman, 1999, 2001; Dow et al., 2006; Goldstein and Gümbel, 2006). Several recent papers provide evidence consistent with a feedback from stock prices to corporate investment (Wurgler, 2000; Durnev et al., 2004; Chen et al., 2007).

has gradually declined in the US over the 20th century (see also Campbell et al., 2001). Moreover, cross-country differences persist after controlling for economy or stock market size and fundamentals correlations. Instead, the authors find that a "good government index" renders the explanatory power of GDP insignificant and that, in the subsample of developed economies, price comovement decreases in the quality of legal investor protection.[21] In their view, this suggests that weak property rights reduce investors' ability to capitalize on, and hence their incentives to search for, firm-specific information.[22]

In this section, I propose a related, perhaps complementary, explanation for the relationship between economic development, public governance and stock price comovement. This explanation presupposes that economic development is associated with technological innovativeness (e.g., Aghion and Howitt, 1992, 1998) and that good public governance is associated with more open media and information sectors (e.g., Djankov et al., 2003; Besley and Prat, 2005). The basic idea is then that technological innovation, in particular in information technology (IT), as well as entry regulations affect the level of competition in the information market. If open to entrants with high innovation potential, information markets are more contestable, thereby making information cheaper. This in turn promotes information diversity and reduces price comovement.

This logic emanates from the previous model when more assets and entry costs are introduced. For simplicity, consider an economy with two assets, $\mathcal{M} = \{1, 2\}$, and three fundamental factors, $\Theta = \{A, B, C\}$. The assets' liquidation values are given by

$$\begin{aligned} \tilde{V}_1 &= \tilde{V}_A + \tilde{V}_B \\ \tilde{V}_2 &= \tilde{V}_A + \tilde{V}_C \end{aligned}$$

The factors are i.i.d. and their variances are given by σ^2. There is one systematic factor (A), whereas the others are idiosyncratic. For simplicity, let $c_B = c_C$.

Liquidity traders invest in the market portfolio so that (a change in) liquidity demand affects each asset in the same way and has a variance of σ_y^2 per asset. Thus, their trades induce market-wide movements (De Long et al., 1990; Morck et al., 2000), which simplifies the analysis but is not crucial for the results. There is a different market-maker for each asset. Trade occurs simultaneously in all assets, and market-makers observe only their own order flow.

As before, only A-data is marketable and there is an incumbent information seller.[23]

[21] The "good government index" comprises measures of corruption, expropriation risk and contract repudiation from La Porta et al. (1999). Investor protection is proxied by the "anti-director rights index" from La Porta et al. (1998) which indicates how accountable corporate insiders are to shareholders.

[22] Jin and Myers (2007) offer an alternative explanation. They suggest that corporate insiders absorb idiosyncratic risk by diverting cash flow within bounds set by market-wide returns. Therefore, dividends and thus prices covary more in countries with weak investor protection (more diversion).

[23] This is similar to assuming that market-wide information is less opaque than firm-specific information (e.g., Jin and Myers, 2006).

Contrary to before, the incumbent's fixed distribution cost K_I is non-negligible, privately known to the incumbent, and commonly known to be continuously distributed on $[K_L, K_H]$. That is, the incumbent has superior knowledge about her own efficiency. To challenge the incumbent, a potential entrant must develop her own communication network. Specifically, she must make an upfront investment of S to produce a technology that distributes information at a fixed cost $K_E < K_L$. Once the outlay S is spent, it is sunk irrespective of the final outcome and so represents an entry cost.[24]

The timing of the entry game (in stage -2) is as follows. First, the incumbent precommits to a price p_A^I, which she can lower but not raise afterwards. Second, the challenger observes p_A^I and then decides whether or not to enter, that is, to develop the technology. Third, if the challenger enters, the two sellers engage in Bertrand competition (in stage -1). Otherwise, the incumbent can choose any price in $\left[0, p_A^I\right]$ at which to provide the information. I solve the game for Pareto-dominant Perfect Bayesian Equilibria.

This game yields a simple solution. Since the incumbent is bound to lose against the challenger if the latter enters, she either surrenders the market or preempts entry. The challenger enters if she expects post-entry profits to be at least as large as the entry costs S. Knowing that, upon entry, the equilibrium price equals the incumbent's break-even price, entry thus requires that

$$\mathrm{E}\left(K_I \left| p_A^I\right.\right) + c_A - (K_E + c_A) \geq S.$$

Thus, the incumbent preempts entry if she can choose p_A^I to signal greater (expected) efficiency than type K_I^+, as defined by

$$K_I^+ = S + K_E,$$

without violating her participation constraint.

Lemma 5 *If* $\mathrm{E}(K_I) \leq S + K_E$*, the information market is uncontestable, and the incumbent engages in predatory pricing irrespective of her type. Otherwise, the market is contestable, and the incumbent deters entry if* $K_I \leq K_I^*$ *and surrenders the market if* $K_I > K_I^*$ *where* $K_I^* < K_H$*. In either case, the price is lower than under monopoly.*

The equilibrium is intuitive. If innovation is not worthwhile when facing an incumbent of average efficiency, entry is deterred without further ado. Hence, the incumbent need not be concerned with signalling high efficiency but can de facto behave like a monopolist. However, if average efficiency is not high enough to deter entry, the incumbent has an incentive to signal higher efficiency because it implies a lower post-entry profit for the challenger. To this end, she commits to prices that a too inefficient type cannot afford

[24] Introducing uncertainty or private information about S or K_E, or allowing for $K_E \geq K_L$, makes the extension more realistic, but the mechanics and basic intuition behind the results remain the same.

to mimic. Thus, sufficiently efficient incumbent types lower their price but successfully defend their market, whereas all other types must give way to a new entrant.[25] The comparative statics are also straightforward: Contestability increases in the potential entrant's efficiency and decreases in entry costs.

Corollary 7 *Lower S or K_E increase entry probability and decrease information prices.*

For the following proposition, I choose a particular interpretation of S and K_E, namely as capturing the country's innovative capacity or technological rate of progress as well as the extent to which entry into the information market is made difficult by regulation. For instance, suppose that the entry cost S is the sum of two cost components, S_1 and S_2, the former representing investments in R&D or technological infrastructure and the latter representing official costs of entry.[26] Then, $(S_1 K_E)^{-1}$ can be interpreted as a measure of (technological) innovativeness and S_2 as the cost of overcoming regulatory "red tape" to enter the information market.

The proposition relates $(S_1 K_E)^{-1}$ and S_2 to patterns of price comovement. Price comovement can, for example, be measured by the average (absolute) correlation coefficient between individual asset prices and the market index:

$$\bar{\rho}_{\mathcal{M}} = |\mathcal{M}|^{-1} \sum_{a \in \mathcal{M}} |\rho_{a\mathcal{M}}|$$

where

$$\rho_{a\mathcal{M}} \equiv \frac{\mathrm{Cov}(p_a, p_{\mathcal{M}})}{\sqrt{\mathrm{Var}(p_a)\mathrm{Var}(p_{\mathcal{M}})}} \quad \text{and} \quad p_{\mathcal{M}} = \sum_{a \in \mathcal{M}} p_a.$$

The average correlation coefficient indicates how much of the variation of a single price is explained by market-wide variations and is typically a good approximation of the R^2 in a regression.

Proposition 7 *Higher rates of technological innovation and more open information markets promote information diversity, which in turn decreases price comovement.*

Like Veldkamp (2006b), the model relates the level of comovement to the amount of firm-specific information that investors acquire. Common to both models is that less synchronous prices are better predictors of future earnings and improve corporate investment decisions, consistent with recent empirical evidence (Wurgler, 2000; Durnev et al., 2003, 2004; Chen et al., 2007). The novelty of Proposition 7 is that it can explain cross-country differences in comovement based on varying levels of information market

[25] Given fixed costs and contestability, increasing the number of sellers (by regulation) need not lower prices. In fact, consolidation may reduce prices as is found, e.g., by Chandra and Collard-Wexler (2007).

[26] Djankov et al. (2002) document a large cross-country variation in entry costs, which tend to be lower in countries with more democratic and limited governments. See also http://www.doingbusiness.org/.

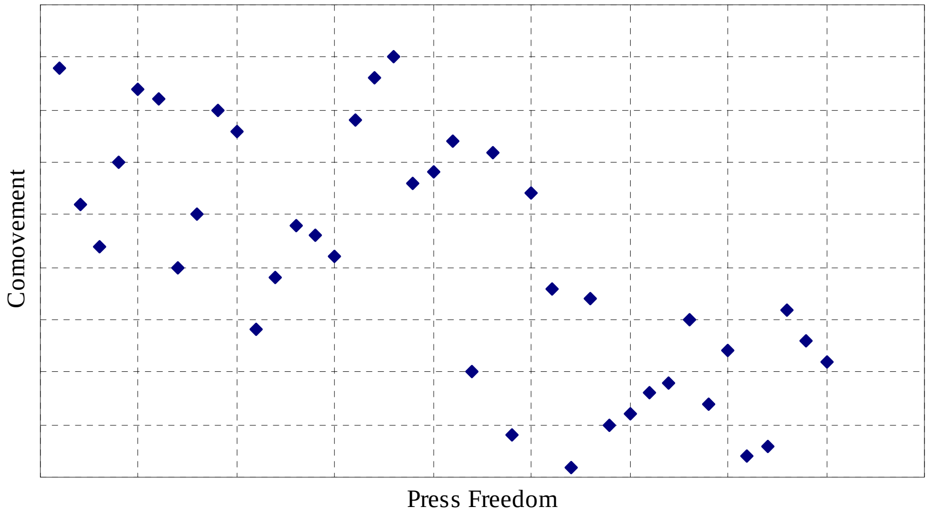


Figure 1: Comovement and press freedom (rankings) for 40 countries

competition. Empirically, if there is a positive relation between per capita GDP and IT innovation as well as between government quality and openness of information markets, Proposition 7 is consistent with the findings in Morck et al. (2000). In Figure 1, I plot a country's rank according to Morck et al.'s R^2-score against its rank according to the press freedom index (as a proxy for the openness of the information sector).[27] Press freedom and comovement are increasing along the axes. The plot suggests a negative relationship between press freedom and comovement. While far from conclusive, this suggests *prima facie* that cross-country analyses of comovement should control for information market characteristics (as, e.g., in Bushman et al., 2004).[28]

Further evidence suggesting a link between information activities and comovement comes from Chan and Hameed (2006). Their cross-country study finds that comovement is higher for stocks followed by more analysts (see also Hameed et al., 2005; Piotroski and Roulstone, 2004). However, this relation is weaker when analyst recommendations are more diverse. This cross-sectional prediction arises in the above model when a (more) idiosyncratic asset is added (e.g., $\tilde{V}_3 = \tilde{V}_D + \tilde{V}_E$). Not only would that asset covary less with the market but it would also attract fewer informed traders than the other assets. This is because information about a common factor ($\tilde{V}_A$) is more valuable, as it can be used for trade in more assets. Also, if sold, data about the common factor is more cheaply available. However, if that data becomes so cheap, and hence widespread, that traders increasingly seek idiosyncratic information (about $\tilde{V}_B$ and $\tilde{V}_C$), the increase in the number

[27] The press freedom index is announced annually by Reporters without Borders (http://www.rsf.org).

[28] This view also suggests that insider trades play a more important role for impounding firm-specific information into prices when information markets are underdeveloped. Indeed, Fernandes and Ferreira (2007) present evidence that the enforcement of insider trading laws decreases comovement in developed markets but has no or even the opposite effect in emerging markets (with poor legal protection).

of informed traders entails an increase in information diversity; and the positive relation between the number of informed traders in a stock and the stock's comovement with the market becomes weaker.[29]

Information-based models, like the present one, can also explain the time-series variation in comovement. First, since a contraction in asset value reduces the value of information (Wilson, 1975), crowding out becomes more likely during recessions, consistent with the observation that comovement is countercyclical (Ribeiro and Veronesi, 2002). This effect is amplified if information is noisier or liquidity dries up in recessions (Corollary 3). Second, continuing decreases in the cost of information can explain the negative trend in comovement. Such decreases may result from IT innovation and deregulation in the information sector. Empirically, it would be interesting to test whether the entry of new information providers, such as Bloomberg in the 1980s, or the recent wave of liberalization in the US and UK media sectors have had a discernible impact on price comovement. Fox et al. (2003) suggest that better information supply indeed reduces comovement.

Real sector variables also exhibit comovement patterns (Comin and Philippon, 2005; Wei and Zhang, 2006; Knyazeva et al., 2007), giving rise to product market explanations (Philippon, 2003; Gaspar and Massa, 2004; Irvine and Pontiff, 2004). Production and information-based explanations are by no means mutually exclusive. For instance, Chun et al. (2007) suggest a mutually reinforcing relationship: More informative prices stimulate a Schumpeterian process of creative destruction, whereby new firms rise and established ones fall. Conversely, such idiosyncratic fundamentals variation encourages investors to acquire firm-specific information. In sum, information activity on financial markets and real sector decisions would jointly create patterns of comovement.[30]

[29] It should be pointed out that the dispersion of analyst recommendations need not necessarily be a sign of information diversity but can also indicate more opaque, i.e. less precise, information. If so, more dispersion indicates less, not more, information (Jin and Myers, 2006). The finding by Chan and Hameed pertains, however, not to the level of dispersion but to its interaction with the number of analysts. Thus, my interpretation presumes that an increase in dispersion indicates an increase in information if it is, at the same time, associated with an increase in analyst coverage.

[30] There are two further explanations for comovement. Barberis et al. (2000) argue that comovement emerges because investors sort assets into categories or trade only a subset of assets. Comovement may also stem from liquidity shocks (Chordia et al., 2000; Pastor and Stambaugh, 2003), although Domowitz et al. (2005) suggest that return commonality and liquidity commonality are distinct phenomena.

7 Conclusions

Research on the impact of information markets on economic decision-making is scarce. Even in areas, such as finance, where information is paramount, the role of media receives little attention (Zingales, 2002). Many economic models treat information acquisition as endogenous, but disregard the incentives of information suppliers. Typically, the price of information is exogenous, and information sources are treated as objects rather than subjects. Given the real-world importance of media in shaping our beliefs, this lack of understanding is unsatisfactory. From an economic perspective, it seems plausible that information sellers can have incentives that induce a suboptimal supply of information, thereby impairing economic outcomes. For instance, they may for various reasons give a biased view (Dyck and Zingales, 2003; Mullainathan and Shleifer, 2005).

In this paper, I examine another possibility: An information seller may set her price with the intention to crowd out other information sources, thereby deliberately reducing information diversity. The setting considers investors who can either purchase or privately generate information to improve their investment decisions in a financial market. I show that information markets may indeed homogenize investor beliefs, but this becomes less likely as competition in the information market increases. This suggests that information market competition may play an important role in financial market development. In fact, the model may yield a theory of (financial and information) market coevolution if the demand of liquidity traders is endogenized.

The channel through which the information seller affects information diversity is asset market liquidity. Specifically, she can, to a certain extent, control liquidity through the supply of information. Thus, the model can potentially be applied to other situations in which the information seller, or any other agent, has a particular interest in manipulating market liquidity or information diversity. In such situations, the supply side incentives of the information market are no longer trivial.

Appendix

Derivation of Selected Formulae

Derivation of Equation (1)

By our assumptions, we have

$$\begin{aligned}
\mathrm{Var}(\tilde{z}) &= \mathrm{Var}\left(\sum_1^{n_A} x_A(\tilde{s}_{iA}) + \sum_1^{n_B} x_B(\tilde{s}_{lB}) + \tilde{y}\right) \\
&= \mathrm{Var}\left(\sum_1^{n_A} \alpha_A \tilde{s}_{iA}\right) + \mathrm{Var}\left(\sum_1^{n_B} \alpha_B \tilde{s}_{lB}\right) + \mathrm{Var}(\tilde{y}) \\
&= \alpha_A^2 \mathrm{Var}\left(\sum_1^{n_A}\left(\tilde{V}_A + \tilde{\epsilon}_i\right)\right) + \alpha_B^2 \mathrm{Var}\left(\sum_1^{n_B}\left(\tilde{V}_B + \tilde{\epsilon}_l\right)\right) + \sigma_y^2 \\
&= \alpha_A^2\left[\mathrm{Var}\left(\sum_1^{n_A} \tilde{V}_A\right) + n_A\sigma_\epsilon^2\right] + \alpha_B^2 \mathrm{Var}\left[\mathrm{Var}\left(\sum_1^{n_B} \tilde{V}_B\right) + n_B\sigma_\epsilon^2\right] + \sigma_y^2 \\
&= \alpha_A^2\left(n_A^2\sigma^2 + n_A\sigma_\epsilon^2\right) + \alpha_B^2\left(n_B^2\sigma^2 + n_B\sigma_\epsilon^2\right) + \sigma_y^2
\end{aligned}$$

Similarly,

$$\begin{aligned}
\mathrm{Cov}(\tilde{V}, \tilde{z}) &= \mathrm{Cov}\left(\tilde{V}, \sum_1^{n_A} x_A(\tilde{s}_{iA}) + \sum_1^{n_B} x_B(\tilde{s}_{iB}) + \tilde{y}\right) \\
&= \mathrm{Cov}\left(\tilde{V}, \sum_1^{n_A} x_A(\tilde{s}_{iA})\right) + \mathrm{Cov}\left(\tilde{V}, \sum_1^{n_B} x_B(\tilde{s}_{iB})\right) \\
&= \mathrm{Cov}\left(\tilde{V}, \sum_1^{n_A} \alpha_A\left(\tilde{V}_A + \tilde{\epsilon}_i\right)\right) + \mathrm{Cov}\left(\tilde{V}, \sum_1^{n_B} \alpha_B\left(\tilde{V}_B + \tilde{\epsilon}_i\right)\right) \\
&= \mathrm{Cov}\left(\tilde{V}_A + \tilde{V}_B, \sum_1^{n_A} \alpha_A \tilde{V}_A\right) + \mathrm{Cov}\left(\tilde{V}_A + \tilde{V}_B, \sum_1^{n_B} \alpha_B \tilde{V}_B\right) \\
&= \mathrm{Cov}\left(\tilde{V}_A, n_A\alpha_A\tilde{V}_A\right) + \mathrm{Cov}\left(\tilde{V}_B, n_B\alpha_B\tilde{V}_B\right) \\
&= (n_A\alpha_A + n_B\alpha_B)\,\sigma^2
\end{aligned}$$

Using these results in $\lambda = \frac{\mathrm{Cov}(\tilde{V},\tilde{z})}{\mathrm{Var}(\tilde{z})}$ leads to equation (1).

Derivation of Equation (3)

Using $\mathrm{E}(\tilde{V}_A \,|s_{iA}) = \mathrm{E}(\,\tilde{s}_{kA}|\, s_{iA}) = \frac{\sigma^2 s_{iA}}{\sigma^2+\sigma_\epsilon^2}$ and $\mathrm{E}(\tilde{V}_B \,|s_{iA}) = \mathrm{E}(\tilde{s}_{lB} \,|s_{iA}) = 0$ in (2) leads to

$$\max_{x_{iA}} \left[\frac{\sigma^2 s_{iA}}{\sigma^2 + \sigma_\epsilon^2} - \lambda\left(x_{iA} + \sum_{1,\theta' \neq i}^{n_A} \alpha_A \frac{\sigma^2 s_{iA}}{\sigma^2 + \sigma_\epsilon^2}\right)\right] x_{iA}.$$

The maximand is quadratic and strictly concave in x_{iA} and therefore has a unique global maximum. The first-order condition yields the solution

$$x_{iA} = \frac{(1 - \lambda(n_A - 1)\alpha_A)\,\sigma^2}{2\lambda\,(\sigma^2 + \sigma_\epsilon^2)} s_{iA}$$

Substituting this in $\alpha_A s_{iA} = x_{iA}$ gives

$$\begin{aligned}
\alpha_A s_{iA} &= \frac{(1 - \lambda(n_A - 1)\alpha_A)\,\sigma^2}{2\lambda\,(\sigma^2 + \sigma_\epsilon^2)} s_{iA} \\
\alpha_A &= \frac{\sigma^2\lambda^{-1}}{\sigma^2(n_A + 1) + 2\sigma_\epsilon^2}
\end{aligned}$$

The derivation for α_B is analogous.

Derivation of Equation (8)

$$\begin{aligned}
\mathrm{I}(n_A, n_B) &= 2\rho^2_{V,z} = \frac{2[\mathrm{Cov}(\tilde{V},\tilde{z})]^2}{\mathrm{Var}(\tilde{V})\mathrm{Var}(\tilde{z})} = \frac{2\mathrm{Cov}(\tilde{V},\tilde{z})}{\mathrm{Var}(\tilde{V})}\lambda \\
&= \frac{2\left(n_A\alpha_A + n_B\alpha_B\right)\sigma^2}{2\sigma^2}\lambda \\
&= \left(n_A\alpha_A + n_B\alpha_B\right)\lambda \\
&= \left(n_A\frac{\sigma^2\lambda^{-1}}{\sigma^2(n_A+1)+2\sigma_\epsilon^2} + n_B\frac{\sigma^2\lambda^{-1}}{\sigma^2(n_B+1)+2\sigma_\epsilon^2}\right)\lambda \\
&= \sum_{\theta=A,B}\frac{n_\theta\sigma^2}{\sigma^2(n_\theta+1)+2\sigma_\epsilon^2}
\end{aligned}$$

where the second step follows from (**??**), the numerator in the second line from (1), and the fourth line from (3).

Proof of Proposition 1

Substituting (3) in (1),

$$\lambda = \frac{\left(n_A\frac{\sigma^2\lambda^{-1}}{\sigma^2(n_A+1)+2\sigma_\epsilon^2} + n_B\frac{\sigma^2\lambda^{-1}}{\sigma^2(n_B+1)+2\sigma_\epsilon^2}\right)\sigma^2}{\frac{\sigma^4\lambda^{-2}}{(\sigma^2(n_A+1)+2\sigma_\epsilon^2)^2}\left(n_A^2\sigma^2 + n_A\sigma_\epsilon^2\right) + \frac{\sigma^4\lambda^{-2}}{(\sigma^2(n_B+1)+2\sigma_\epsilon^2)^2}\left(n_B^2\sigma^2 + n_B\sigma_\epsilon^2\right) + \sigma_y^2}.$$

Cross-multiplying and solving for λ yields (as a positive solution)

$$\lambda = \frac{\sigma^2}{\sigma_y}\left[\frac{n_A\left(\sigma^2+\sigma_\epsilon^2\right)}{[(n_A+1)\sigma^2+2\sigma_\epsilon^2]^2} + \frac{n_B\left(\sigma^2+\sigma_\epsilon^2\right)}{[(n_B+1)\sigma^2+2\sigma_\epsilon^2]^2}\right]^{1/2}$$

which is the first part of (4). Using this result in (3) yields the second part of (4).

To see that the positive solution is the unique solution to (2), note that its second-order condition is given by $-2\lambda < 0$. ■

Proof of Corollary 2

The first and second derivatives of $T(n_\theta)$ are respectively

$$T'(n_\theta) = \frac{\left(\sigma^2+\sigma_\epsilon^2\right)\left(2\sigma_\epsilon^2+\sigma^2-n_\theta\sigma^2\right)}{[(n_\theta+1)\sigma^2+2\sigma_\epsilon^2]^3}$$

and

$$T''(n_\theta) = \frac{2\sigma^2\left(\sigma^2+\sigma_\epsilon^2\right)\left(n_\theta\sigma^2-2\sigma^2-4\sigma_\epsilon^2\right)}{[(n_\theta+1)\sigma^2+2\sigma_\epsilon^2]^4}.$$

Note that

$$T'(n_\theta) \geqslant 0 \Leftrightarrow 2\sigma_\epsilon^2+\sigma^2-n_\theta\sigma^2 \geqslant 0 \Leftrightarrow n_\theta \leqslant \frac{2\sigma_\epsilon^2+\sigma^2}{\sigma^2} \equiv \overline{n}_\theta$$

and

$$T''(n_\theta) \leqslant 0 \Leftrightarrow n_\theta\sigma^2-2\sigma^2-4\sigma_\epsilon^2 \leqslant 0 \Leftrightarrow n_\theta \leqslant 2\overline{n}_\theta.$$

This completes the proof.■

Proof of Lemma 1

Given that c_θ is a constant, I need only consider the behavior of $\rho_\theta(n_\theta, n_{\theta'})$ or, more precisely,

$$\begin{aligned}
\rho_\theta(n_\theta, n_{\theta'}) &= \mathrm{E}[(\tilde{V}-\tilde{p})\tilde{x}_{i\theta}] = \mathrm{E}[(\tilde{V}-\lambda\tilde{z})\alpha_\theta\tilde{s}_{i\theta}] \\
&= \alpha_\theta\mathrm{E}(\tilde{V}\tilde{s}_{i\theta}) - \lambda\mathrm{E}\left[\left(\sum_{\hat{\imath}=1}^{n_\theta}\alpha_\theta\tilde{s}_{\hat{\imath}\theta} + \sum_{l=1}^{n_{\theta'}}\alpha_{\theta'}\tilde{s}_{l\theta'} + \tilde{y}\right)\alpha_\theta\tilde{s}_{i\theta}\right] \\
&= \alpha_\theta\left[\mathrm{E}\left(\tilde{V}_\theta\tilde{s}_{i\theta}\right) + \mathrm{E}\left(\tilde{V}_{\theta'}\tilde{s}_{i\theta}\right)\right] - \lambda\left[\sum_{i=1}^{n_\theta}\alpha_\theta^2\mathrm{E}(\tilde{s}_{\hat{\imath}\theta}\tilde{s}_{i\theta}) + \sum_{l=1}^{n_{\theta'}}\alpha_{\theta'}\alpha_\theta\mathrm{E}(\tilde{s}_{l\theta'}\tilde{s}_{i\theta}) + \alpha_\theta\mathrm{E}(\tilde{y}\tilde{s}_{i\theta})\right].
\end{aligned}$$

Since $\mathrm{E}\left(\tilde{V}_\theta \tilde{s}_{i\theta}\right) = \sigma^2$, $\mathrm{E}\left(\tilde{V}_{\theta'} \tilde{s}_{i\theta}\right) = 0$, $\mathrm{E}\left(\tilde{s}_{i\theta}^2\right) = \sigma^2 + \sigma_\epsilon^2$, $\mathrm{E}(\tilde{s}_{i\theta}\tilde{s}_{i\theta}) = \sigma^2$, $\mathrm{E}\left(\tilde{s}_{l\theta'}\tilde{s}_{i\theta}\right) = 0$, and $\mathrm{E}\left(\tilde{y}\tilde{s}_{i\theta}\right) = 0$ for all i and all $\theta', l \neq i$, this becomes

$$\rho_\theta(n_\theta, n_{\theta'}) = \alpha_\theta \sigma^2 \left(1 - \lambda n_\theta \alpha_\theta\right) = \alpha_\theta \sigma^2 \left[\frac{\sigma^2 + 2\sigma_\epsilon^2}{(n_\theta + 1)\,\sigma^2 + 2\sigma_\epsilon^2}\right] \tag{9}$$

where the last equality follows from (3). Substituting (4) and (5) into (9) gives

$$\rho_\theta(n_\theta, n_{\theta'}) = \left[\frac{\sigma_y \sigma^2 \left(\sigma^2 + 2\sigma_\epsilon^2\right)}{\left[\sigma^2\left(n_\theta + 1\right) + 2\sigma_\epsilon^2\right]^2}\right]\left[\frac{n_\theta\left(\sigma^2 + \sigma_\epsilon^2\right)}{\left[(n_\theta + 1)\sigma^2 + 2\sigma_\epsilon^2\right]^2} + T_{\theta'}\right]^{-1/2}.$$

Now define $A \equiv \left[\rho_\theta(n_\theta, n_{\theta'})\right]^{-2}$. This gives

$$A = \frac{n_\theta\left(\sigma^2 + \sigma_\epsilon^2\right)\left[\sigma^2\left(n_\theta + 1\right) + 2\sigma_\epsilon^2\right]^2}{\sigma_y^2 \sigma^4 \left(\sigma^2 + 2\sigma_\epsilon^2\right)^2} + \frac{\left[\sigma^2\left(n_\theta + 1\right) + 2\sigma_\epsilon^2\right]^4}{\sigma_y^2 \sigma^4 \left(\sigma^2 + 2\sigma_\epsilon^2\right)^2} T_{\theta'}.$$

A strictly increases in n_θ, which proves (a). Corollary 2 identifies the unique maximum of $T_{\theta'}$. For constant n_θ, this maximum coincides with a unique minimum of A, which proves (b). The proof of (c) proceeds in steps (i)-(iii).
(i) First define the functions

$$\lambda^n\left(n_\theta\right) \equiv \frac{\sigma^2}{\sigma_y}\left[\frac{n_\theta\left(\sigma^2 + \sigma_\epsilon^2\right)}{\left[(n_\theta + 1)\sigma^2 + 2\sigma_\epsilon^2\right]^2} + \frac{\left(n - n_\theta\right)\left(\sigma^2 + \sigma_\epsilon^2\right)}{\left[(n - n_\theta + 1)\sigma^2 + 2\sigma_\epsilon^2\right]^2}\right]^{1/2}$$

and

$$\alpha_\theta^n\left(n_\theta\right) \equiv \frac{\sigma^2\left[\lambda^n\left(n_\theta\right)\right]^{-1}}{\sigma^2(n_\theta + 1) + 2\sigma_\epsilon^2}.$$

Note $\lambda^n\left(n_\theta\right)$ and hence $\alpha_\theta^n\left(n_\theta\right)$ are continuously differentiable for $n_\theta \in [0, n]$. Using the first equality in (9), I write

$$\rho_\theta(n_\theta, n - n_\theta) \equiv \rho_\theta^n\left(n_\theta\right) = \alpha_\theta^n\left(n_\theta\right)\sigma^2\left[1 - n_\theta \alpha_\theta^n\left(n_\theta\right)\lambda^n\left(n_\theta\right)\right].$$

Since this is an algebraic combination of continuously differentiable functions for $n_\theta \in [0, n]$, it is also continuously differentiable for $n_\theta \in [0, n]$.
(ii) Consider (9) again. Note that the term in parentheses decreases in n_θ. Moreover, by Corollary 1, $n_\theta < n_{\theta'} \Leftrightarrow \alpha_\theta > \alpha_{\theta'}$. Hence, $n_\theta < n_{\theta'} \Leftrightarrow \rho_\theta^n(n_\theta) > \rho_{\theta'}^n(n_{\theta'})$ (*).

Simple inspection of the formulae in Lemma 1 shows that, for a fixed population, a trader from group θ with $n_\theta = x$ faces exactly the same decision problem as would a trader from group θ' with $n_{\theta'} = x$. That is, $\rho_\theta^n\left(x\right) = \rho_{\theta'}^n\left(x\right)$. Together with equivalence (*), this implies that

$$\rho_\theta^n\left(n_\theta\right) > \rho_\theta^n\left(n - n_\theta\right) \quad \text{for } n_\theta \in \left(0, n/2\right),$$

which in turn implies that $\rho_\theta^n\left(n_\theta\right)$ is decreasing over some range in $[0, n]$.
(iii) Now suppose that $\rho_\theta^n\left(n_\theta\right)$ is also increasing over some range in $[0, n]$. Since $\rho_\theta^n\left(n_\theta\right)$ is continuously differentiable, this requires the existence of some $x^* \in (0, n)$ such that $\frac{\partial \rho_\theta^n}{\partial n_\theta}\left(x^*\right) = 0$. Using Proposition 1 and $n_{\theta'} = n - n_\theta$ to eliminate α_θ, λ and $n_{\theta'}$ from $\rho_\theta^n(n_\theta)$, I verify (in *Maple*) that $\frac{\partial \rho_\theta^n}{\partial n_1}\left(x^*\right) = 0$ has no real solution. By contradiction, $\rho_\theta^n\left(n_\theta\right)$ is strictly decreasing in $[0, n]$. This proves part (c). ■

Proof of Proposition 2

Preliminary. I show that $\pi_A\left(n_A, 0\right) = \pi_B\left(1, n_A\right)$ has a unique solution. That they cross at least once follows from parts (a) and (b) of Lemma 1. To show that they cross at most once, it suffices to show that $\rho_A\left(n_A, 0\right) = \rho_B\left(1, n_A\right)$ has a unique solution. After substituting (4) and (5) into (9), the respective functions are given by

$$\begin{aligned} \rho_A(n_A, 0) &= \frac{\sigma_y \sigma^2\left(\sigma^2 + 2\sigma_\epsilon^2\right)}{\left[\left(n_A + 1\right)\sigma^2 + 2\sigma_\epsilon^2\right]\sqrt{n_A\left(\sigma^2 + \sigma_\epsilon^2\right)}} \\ \rho_B(1, n_A) &= \frac{\sigma^2 \sigma_y\left(\sigma^2 + 2\sigma_\epsilon^2\right)\left((n_A + 1)\sigma^2 + 2\sigma_\epsilon^2\right)}{2\left(\sigma^2 + \sigma_\epsilon^2\right)^{3/2}\sqrt{\left((n_A + 1)\sigma^2 + 2\sigma_\epsilon^2\right)^2 + 4m_A\left(\sigma^2 + \sigma_\epsilon^2\right)^2}} \end{aligned}$$

Equating these expressions and rearranging yields

$$1 = \frac{\left(\left(n_A + 1\right)\sigma^2 + 2\sigma_\epsilon^2\right)^2\sqrt{n_A}}{2\left(\sigma^2 + \sigma_\epsilon^2\right)\sqrt{\left((n_A + 1)\sigma^2 + 2\sigma_\epsilon^2\right)^2 + 4m_A\left(\sigma^2 + \sigma_\epsilon^2\right)^2}}$$

On both sides, I square, take the inverse and further rearrange to get

$$4\left(\sigma^2+\sigma_\epsilon^2\right)^2\left(\frac{1}{\left(\left(n_A+1\right)\sigma^2+2\sigma_\epsilon^2\right)^2 n_A}+\frac{1}{\left(\left(n_A+1\right)\sigma^2+2\sigma_\epsilon^2\right)^4}\right)=1.$$

The left-hand side goes to infinity for $n_A \to 0$ and strictly decreases in n_A. Thus, $\pi_A(n_A,0)=\pi_B(1,n_A)$ has exactly one solution, to the left of which $\pi_A(n_A,0)>\pi_B(1,n_A)$ and to the right of which $\pi_A(n_A,0)<\pi_B(1,n_A)$.

First Part. I start with the *sufficient condition*, $\underline{n}_A \leqslant n_A^0 \leqslant \overline{n}_A \Rightarrow \left(n_A^*,n_B^*\right)=\left(n_A^0,0\right)$. It is straightforward to verify that the set of inequalities $\underline{n}_A \leqslant n_A^0 \leqslant \overline{n}_A$ is equivalent to the condition $\pi_B\left(1,n_A^0\right)\leqslant \pi_A\left(n_A^0,0\right)=0$. Suppose that this condition holds. I now check different candidate equilibria. (i) Note that $\left(n_A^0,0\right)$ trivially satisfies the free-entry condition. (ii) Conjecture an equilibrium with $n_A>n_A^0$ and $n_B\geqslant 0$. For all $n_A>n_A^0$, $\pi_A(n_A,n_B)<\pi_A\left(n_A^0,n_B\right)<\pi_A\left(n_A^0,0\right)=0$, that is, A-traders would incur a loss. Hence this cannot be an equilibrium. (iii) Conjecture an equilibrium with $n_A<n_A^0$ and $n_B\geqslant 0$ and distinguish the cases (iiia) $n_A+n_B=n\leqslant n_A^0$ and (iiib) $n_A+n_B>n_A^0$.
(iiia) Note that $\pi_A(n,0)>\pi_B(1,n-1)$. Given that $n<n_A^0$, this follows from the initial assumption $\pi_A\left(n_A^0,0\right)\geqslant \pi_B\left(1,n_A^0\right)$ and that $\pi_A(n_A,0)$ and $\pi_B(1,n_A)$ cross only once. Then, by Lemma 1(c), $\pi_A(n,0)<\pi_A(n-1,1)<\cdots<\pi_A(1,,-1)$ whereas $\pi_B(1,n-1)>\pi_B(2,n-2)>\cdots>\pi_B(n-1,1)$. Thus, this cannot be an equilibrium because, for any (n_A,n_B) such that $n_A+n_B\leqslant n_A^0$, B-traders would on the margin switch to A-data.
(iiib) Denote $n_B=n_A^0-n_A$ so that $n_B>n_B$ (because $n_A<n_A^0$). This provided, note that $\pi_A\left(n_A^0,0\right)=0>\pi_B\left(1,n_A^0-1\right)\geqslant\pi_B(n_B,n_A)>\pi_B(n_B,n_A)$. The first two inequalities follow from Lemma 1(c), and the last inequality follows from Lemma 1(a). Together, they imply that this cannot be an equilibrium because B-traders would expect to make a loss.
Finally, the *necessary condition*, $\left(n_A^*,n_B^*\right)=\left(n_A^0,0\right)\Rightarrow\pi_B\left(1,n_A^0\right)\leqslant\pi_A\left(n_A^0,0\right)$, holds because, if the latter inequality were violated, A-traders would on the margin switch to B-data, and $\left(n_A^0,0\right)$ would not be an equilibrium.

Second Part. I must show that, when $n_A^0\notin\left(\underline{n}_A,\overline{n}_A\right)$, there exists a unique pair $\left(n_A^*,n_B^*\right)$ that satisfies $n_A^*>n_B^*>0$ and $\pi_\theta(n_\theta^*,n_{\theta'}^*)=0$ for $\theta=A,B$. I proceed in steps (i)-(vi).
(i) Note that neither $(0,0)$, $(0,n_B)$ nor $(n_A,0)$ can be an equilibrium. This follows respectively from $\pi_\theta(1,0)>0$ for $\theta=A,B$, $\pi_A(1,n_B-1)>\pi_B(n_B,0)$ (Lemma 1 (c) and $c_A\leqslant c_B$), and the proof for the first part of the proposition.
(ii) Note that there exists an information structure where positive profits are equally shared. Consider a point n where $\pi_B(1,n)>\pi_A(n,0)>0$, whose existence follows from $n_A^0\notin\left(\underline{n}_A,\overline{n}_A\right)$. Ignoring integer problems, this implies that it is on the margin profitable for an A-trader to instead become a B-trader. In doing so, she marginally lowers the expected profit in the B-group but marginally raises it in the A-group (Lemma 1 (c)). Still, it might still be profitable for the next marginal A-trader to switch. However, since $\pi_B(n-1,1)<\pi_A(1,n-1)$ and the profit functions are continuous, there exists a unique x where $\pi_B(n-x^*,x^*)=\pi_A(x^*,n-x^*)$. Given $\pi_A(n,0)>0$, profits must be positive for both groups.
(iii) It follows from the monotonicity in Lemma 1 (c) that such an indifference point exists for any n (though not always with positive profits).
(iv) If – starting from $\pi_B(n_B,n_A)=\pi_A(n_A,n_B)>0$ – the total population is changed, both n_A and n_B have to move in the same direction to maintain the indifference. To see this, note that after substituting (4) and (5) into (9), $\pi_A(n_A,n_B)=\pi_B(n_A,n_B)$ can be written out and rearranged to

$$\left(\frac{1}{\left(\left(n_A+1\right)\sigma^2+2\sigma_\epsilon^2\right)^2}-\frac{1}{\left(\left(n_B+1\right)\sigma^2+2\sigma_\epsilon^2\right)^2}\right)=\frac{c_A-c_B}{\sigma^4\left(\sigma^2+2\sigma_\epsilon^2\right)}\lambda$$

Suppose this holds for a given n_A and n_B. Now suppose that the change in population lowers λ. In order for the equation to still hold, we need that the term in the parentheses to the left becomes smaller. It cannot be that only one group increases (or decreases), because, if so, the group that does not grow in size would end up with positive profits (lower price impact, same or less number of traders). To maintain the equality, both groups have to increase (decrease) when λ falls (rises).
(v) As both groups increase, aggregate expected profits eventually decrease (and even become negative). To see this, write them as

$$\begin{aligned} n_A\frac{\sigma^2\sigma_y\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left(\left(n_A+1\right)\sigma^2+2\sigma_\epsilon^2\right)^2}\left(\frac{n_A\left(\sigma^2+\sigma_\epsilon^2\right)}{\left[(n_A+1)\sigma^2+2\sigma_\epsilon^2\right]^2}+\frac{n_B\left(\sigma^2+\sigma_\epsilon^2\right)}{\left[(n_B+1)\sigma^2+2\sigma_\epsilon^2\right]^2}\right)^{-1/2}-n_Ac_A \\ +n_B\frac{\sigma^2\sigma_y\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left(\left(n_B+1\right)\sigma^2+2\sigma_\epsilon^2\right)^2}\left(\frac{n_A\left(\sigma^2+\sigma_\epsilon^2\right)}{\left[(n_A+1)\sigma^2+2\sigma_\epsilon^2\right]^2}+\frac{n_B\left(\sigma^2+\sigma_\epsilon^2\right)}{\left[(n_B+1)\sigma^2+2\sigma_\epsilon^2\right]^2}\right)^{-1/2}-n_Bc_B= \\ \sigma^2\sigma_y\left(\frac{n_A\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left(\left(n_A+1\right)\sigma^2+2\sigma_\epsilon^2\right)^2}+\frac{n_B\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left(\left(n_B+1\right)\sigma^2+2\sigma_\epsilon^2\right)^2}\right)^{1/2}-n_Ac_A-n_Bc_B \end{aligned}$$

The first expression, total trading profits, is concave in the sense that, if both n_A and n_B increase the marginal trading gain decreases. Moreover, total trading profits converge to zero as $n_A+n_B\to 0$. By contrast, the information costs increase linearly in n_A+n_B.
(vi) Since the above functions are continuous, the preceding arguments imply that – starting from $\pi_B(n_B,n_A)=\pi_A(n_A,n_B)>0$ – there exist a unique population size $n^*>n_A+n_B$ such that, at the respective indifference point, total trading profits and hence average trading profits are zero. This point identifies the unique equilibrium information structure. ■

Proof of Lemma 3

First, note that price discrimination without rationing at each price is equivalent to selling unlimited subscriptions at the lowest offered price.

Second, consider price-quantity schedules of the following form: The seller determines a set of prices $p_A^n > p_A^{n-1} > \cdots > p_A^1$ and the maximum number of subscriptions $y_A^1, y_A^2, \ldots, y_A^n$ she is willing to sell at each price. Suppose that a quantity restriction is binding in the sense that more traders would like to purchase a subscription at that price, say p_A^i. There are two possible cases. (i) If it is unprofitable for any additional trader to purchase data at p_A^{i+1}, the information seller fares better by increasing y_A^i and hence the number of subscriptions sold at p_A^i. (ii) If there are traders who purchase data at p_A^{i+1}, the information seller fares better by setting $y_A^i = 0$. To see this, note that all A-traders make the same trading profit, irrespective of the individual price paid for the data. Thus, if some traders do not incur a loss when buying data at p_A^{i+1}, the y_A^i traders that buy data at p_A^i make a (total) profit of at least $y_A^i(p_A^i - p_A^{i+1})$. When $y_A^i = 0$, these traders would be willing to buy subscriptions at p_A^{i+1}. Thus, having a binding quantity restriction is not optimal. But quantity restrictions that are not binding are unnecessary.

Finally, consider the indirect sale of information, e.g., through a fund. In this case, the seller trades on behalf of its subscribers, and a contract prespecifies a fixed subscription fee and a profit-sharing rule. If only a fixed fee is paid, the seller's trading strategy and hence the fund's expected profit is equivalent to that of a single trader. That is, the seller is better off directly selling the data (to many traders). Now suppose that the sharing rule induces the seller to trade as aggressively as n_A traders. That is, the fund's expected profit will be equal to the combined expected profit of n_A individual traders with *exactly* the same signal. Competition is more intensive for any number of traders with 'photocopied' errors than for the same number of traders with 'personalized' errors (Admati and Pfleiderer, 1986). This is because, in the first case, the traders commonly know that all of them will submit identical orders, perfectly reinforcing each other's impact on the price. As a result, selling data to n_A traders that interpret it differently generates a higher expected profit than trading as aggressively as n_A traders with the same signal. Since the seller extracts the entire trading profits of her subscribers, she is better of selling her signal directly. ■

Proof of Proposition 3

Suppose that $n_A^0(c_A) < \underline{n}_A$ and define p_A^n by $n_A^0(p_A^n) = \underline{n}_A$. Now consider any price $p_A \in \left({}_A^n, c_A\right]$. For any such price, $n_A^0(p_A) < \underline{n}_A$, both types of data will be acquired in equilibrium, and the monopolist's gross profit (which is equal to A-traders' total trading profits) is given by

$$\begin{aligned}
\Pi_A^g(n_A, n_B) &= n_A \frac{\sigma^2 \sigma_y \left(\sigma^2 + 2\sigma_\epsilon^2\right)}{\left((n_A+1)\sigma^2 + 2\sigma_\epsilon^2\right)^2} \left(\frac{n_A\left(\sigma^2+\sigma_\epsilon^2\right)}{[(n_A+1)\sigma^2 + 2\sigma_\epsilon^2]^2} + \frac{n_B\left(\sigma^2+\sigma_\epsilon^2\right)}{[(n_B+1)\sigma^2+2\sigma_\epsilon^2]^2} \right)^{-1/2} \\
&= \frac{\sigma^2\sigma_y\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left(\sigma^2+\sigma_\epsilon^2\right)} \left(\frac{\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)^2}{n_A\left(\sigma^2+\sigma_\epsilon^2\right)} + \frac{n_B}{n_A^2\left(\sigma^2+\sigma_\epsilon^2\right)} \frac{\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)^4}{\left((n_B+1)\sigma^2+2\sigma_\epsilon^2\right)^2} \right)^{-1/2}.
\end{aligned}$$

Now suppose that the monopolist lowers the price to p_A^n, thereby crowding out all B-traders. Her gross profit in this case is given by

$$\begin{aligned}
\Pi_A^g\left(n_A^l, 0\right) &= \underline{n}_A \frac{\sigma^2\sigma_y\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left((\underline{n}_A+1)\sigma^2+2\sigma_\epsilon^2\right)^2} \left(\frac{\underline{n}_A\left(\sigma^2+\sigma_\epsilon^2\right)}{\left((\underline{n}_A+1)\sigma^2+2\sigma_\epsilon^2\right)^2} \right)^{-1/2} \\
&= \frac{\sigma^2\sigma_y\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left(\sigma^2+\sigma_\epsilon^2\right)} \left(\frac{\underline{n}_A\left(\sigma^2+\sigma_\epsilon^2\right)}{\left((\underline{n}_A+1)\sigma^2+2\sigma_\epsilon^2\right)^2} \right)^{1/2} \\
&= \frac{\sigma^2\sigma_y\left(\sigma^2+2\sigma_\epsilon^2\right)\sqrt{\underline{n}_A\left(\sigma^2+\sigma_\epsilon^2\right)}}{\left(\sigma^2+\sigma_\epsilon^2\right)\left((\underline{n}_A+1)\sigma^2+2\sigma_\epsilon^2\right)}
\end{aligned}$$

It is straightforward but tedious to show that $\underline{n}_A > n_A$. I therefore omit the proof, which rests on the logic that, unless their number increases in response to a fall in p_A, A-traders would earn a positive profit (which cannot be an equilibrium).

I now need to show that $\Pi_A^g(\underline{n}_A, 0) > \Pi_A^g(n_A, n_B)$ or, equivalently, that

$$\begin{aligned}
\frac{\Pi_A^g(\underline{n}_A, 0)}{\Pi_A^g(n_A, n_B)} &= \frac{\frac{\sigma^2\sigma_y\left(\sigma^2+2\sigma_\epsilon^2\right)\sqrt{\underline{n}_A\left(\sigma^2+\sigma_\epsilon^2\right)}}{\left(\sigma^2+\sigma_\epsilon^2\right)\left((\underline{n}_A+1)\sigma^2+2\sigma_\epsilon^2\right)}}{\frac{\sigma^2\sigma_y\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left(\sigma^2+\sigma_\epsilon^2\right)} \left(\frac{\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)^2}{n_A\left(\sigma^2+\sigma_\epsilon^2\right)} + \frac{n_B}{n_A^2\left(\sigma^2+\sigma_\epsilon^2\right)} \frac{\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)^4}{\left((n_B+1)\sigma^2+2\sigma_\epsilon^2\right)^2} \right)^{-1/2}} \\
&= \frac{\sqrt{\underline{n}_A\left(\sigma^2+\sigma_\epsilon^2\right)}}{\left((\underline{n}_A+1)\sigma^2+2\sigma_\epsilon^2\right)} \left(\frac{\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)^2}{n_A\left(\sigma^2+\sigma_\epsilon^2\right)} + \frac{n_B}{n_A^2\left(\sigma^2+\sigma_\epsilon^2\right)} \frac{\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)^4}{\left((n_B+1)\sigma^2+2\sigma_\epsilon^2\right)^2} \right)^{1/2}.
\end{aligned}$$

is greater than one. The latter condition can be rewritten as

$$1 + \frac{n_B}{n_A} \frac{\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)^2}{\left((n_B+1)\sigma^2+2\sigma_\epsilon^2\right)^2} > \frac{n_A}{\underline{n}_A}$$

$$1+\frac{\frac{n_B}{\left((n_B+1)\sigma^2+2\sigma_\epsilon^2\right)^2}}{\frac{n_A}{\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)^2}} > \frac{\frac{n_A}{\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)^2}}{\frac{\underline{n}_A}{\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)^2}}. \tag{10}$$

Clearly, the left-hand side is strictly greater than one, whereas the right-hand side is strictly smaller than one due to $n_A < \underline{n}_A$. Thus, (10) holds for any $p_A \in \left(p_A^n, c_A\right]$, and the proposition follows. ■

Proof of Proposition 4

First, showing that information sellers just break even in equilibrium follows the standard proof for Bertrand competition. Second, note that there can only be one seller in equilibrium. Suppose more than one seller sells data and breaks even. Then each of the seller has an incentive to marginally lower their price, in which case they would attract all buyers and make a positive profit since their costs remain constant. Third, that the single information seller in equilibrium sets $p_A^c < p_A^n$ follows from the discussion in the text.

Now consider $p_A \in \left[p_A^h, p_A^n\right]$ where p_A^h is uniquely defined by $n_A^0(p_A^h) = \overline{n}_A$. For all these prices, $\underline{n}_A \leqslant n_A^0(p_A) \leqslant \overline{n}_A$ and hence $n_B^* = 0$ by Proposition 2. In addition, it follows from the second part, step (v), of the proof of Proposition 2 that $\partial\Pi_A^g(n_A,0)/\partial n_A < 0$ for all n_A. Thus, for $n_B = 0$ by assumption, there exists a unique $n_A^*(p_A^0)$ such that aggregate trading profits equal $K + c_A$, i.e.,

$$\sigma^2\sigma_y\left(\frac{n_A^*(p_A^0)\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left(\left(n_A^*(p_A^0)+1\right)\sigma^2+2\sigma_\epsilon^2\right)^2}\right)^{1/2} - n_A^*(p_A^0)c_A = K + c_A. \tag{11}$$

The information seller would never post a price lower than p_A^0. She would incur a loss, even if no B-traders enter the market, and even more so if they do. If $p_A^0 > p_A^h$ and hence $n_A^*(p_A^0) < \overline{n}_A$, the equilibrium price is thus $n_A^c = p_A^0$, and no B-data is collected. To see that this inequality can hold, recall that $\overline{n}_A$ is defined by the larger n_A that solves $\rho_B(1, n_A) = c_B$ or, more precisely,

$$\frac{\sigma^2\sigma_y\left(\sigma^2+2\sigma_\epsilon^2\right)\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)}{2\left(\sigma^2+\sigma_\epsilon^2\right)^{3/2}\sqrt{\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)^2+4m_A\left(\sigma^2+\sigma_\epsilon^2\right)^2}} = c_B$$

$$\frac{n_A}{\left((n_A+1)\sigma^2+2\sigma_\epsilon^2\right)^2} = \frac{1}{4\left(\sigma^2+\sigma_\epsilon^2\right)^2} - \frac{\sigma^4\sigma_y^2\left(\sigma^2+2\sigma_\epsilon^2\right)^2}{16c_B^2\left(\sigma^2+\sigma_\epsilon^2\right)^5} \tag{12}$$

(from the preliminary in the proof of Proposition 2). Note that in (11) the left-hand side decreases faster for higher c_A, and the right-hand side is larger for higher c_A and K. Thus, $n_A^*(p_A^0)$ decreases in c_A and K. (By the way, this proves Corollary 6.) In fact, we can let $n_A^*(p_A^0) \to \underline{n}_A$ by increasing either. By comparison, (12) and hence $\overline{n}_A$ is independent of both c_A and K. Thus, I can make $n_A^*(p_A^0) < \overline{n}_A$ hold, e.g., by increasing K. ■

Proof of Corollary 6

See proof of Proposition 4.

Proof of Proposition 5

I need to show that total trading profits are lower under $(\underline{n}_A, 0)$ than under (n_A, n_B). First, note that $\pi_A(n_A+n_B, 0) < \pi_A(n_A, n_B) = \pi_B(n_B, n_A)$ where the inequality follows from Proposition 1 (c), and the equality follows from the fact that (n_A, n_B) denotes in this case an equilibrium structure. These relations imply that

$$(n_A+n_B)\,\pi_A(n_A+n_B,0) < n_A\pi_A(n_A,n_B) + n_B\pi_B(n_B,n_A).$$

This inequality can be rearranged to

$$\begin{aligned}
(n_A+n_B)\left[\rho_A(n_A+n_B,0)-c_A\right] &< n_A\left[\rho_A(n_A,n_B)-c_A\right]+n_B\left[\rho_B(n_B,n_A)-c_B\right]\\
(n_A+n_B)\,\rho_A(n_A+n_B,0)-(n_A+n_B)\,c_A &< n_A\rho_A(n_A,n_B)+n_B\rho_B(n_B,n_A)-n_Ac_A-n_Bc_B\\
(n_A+n_B)\,\rho_A(n_A+n_B,0) &< n_A\rho_A(n_A,n_B)+n_B\rho_B(n_B,n_A)-n_B\left(c_B-c_A\right)
\end{aligned}$$

which – due to $c_B > c_A$ – implies

$$(n_A+n_B)\,\rho_A(n_A+n_B,0) < n_A\rho_A(n_A,n_B)+n_B\rho_B(n_B,n_A)$$

where the left-hand side and the right-hand side represent total trading profits for $(n_A+n_B, 0)$ and (n_A, n_B) respectively. Finally, it is well-known that $n\rho_A(n,0) < (n')\,\rho_A(n',0)$ if $n' > n$ (see, e.g., Admati and Pfleiderer, 1988). Since $n' > n_A + n_B$, it follows that

$$\underline{n}_A\rho_A(\underline{n}_A,0) < (n_A+n_B)\,\rho_A(n_A+n_B,0) < n_A\rho_A(n_A,n_B)+n_B\rho_B(n_B,n_A)$$

which proves the proposition. ■

Proof of Lemma 4

Recalling (8), note that

$$\frac{\partial \mathrm{I}\left(n_\theta, n_{\theta'}\right)}{\partial n_\theta} = \frac{\sigma^2\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left[\sigma^2(n_\theta+1)+2\sigma_\epsilon^2\right]^2} > 0$$

This proves the first part.

For the second part, note that

$$\mathrm{I}\left(n_A, n-n_A\right) = \frac{n_A\sigma^2}{\sigma^2(n_A+1)+2\sigma_\epsilon^2} + \frac{\left(n-n_A\right)\sigma^2}{\sigma^2(n-n_A+1)+2\sigma_\epsilon^2}$$

is continuously differentiable in n_A for $n_A \in [0,n]$. Partially differentiating with respect to n_A gives

$$\frac{\partial \mathrm{I}\left(n_A, n-n_A\right)}{\partial n_A} = \frac{\sigma^2\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left[\sigma^2(n_A+1)+2\sigma_\epsilon^2\right]^2} - \frac{\sigma^2\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left[\sigma^2(n-n_A+1)+2\sigma_\epsilon^2\right]^2}.$$

For $n_A \in [0,n]$, this term is positive if and only if

$$\begin{aligned}\left[\sigma^2(n_A+1)+2\sigma_\epsilon^2\right]^2 &< \left[\sigma^2(n-n_A+1)+2\sigma_\epsilon^2\right]^2 \\ n_A &< n/2\end{aligned}$$

and analogously negative if and only if $n_A > n/2$. Hence, $\mathrm{I}\left(n_A, n-n_A\right)$ has a global minimum at $n_A = n/2$ for $n_A \in [0,n]$. ■

Proof of Proposition 6

Suppose that $n_A^0(c_A) < \underline{n}_A$, and denote the equilibrium information structure simply by (n_A, n_B). Price informativeness is measured by

$$\mathrm{I}\left(n_A, n_B\right) = \sum_{\theta=A,B} \frac{n_\theta\sigma^2}{\sigma^2(n_\theta+1)+2\sigma_\epsilon^2}.$$

From Proposition 3 follows that the information structure under a monopolistic seller is $(\underline{n}_A, 0)$ with price informativeness

$$\mathrm{I}\left(\underline{n}_A, 0\right) = \frac{\underline{n}_A\sigma^2}{\sigma^2(\underline{n}_A+1)+2\sigma_\epsilon^2}.$$

I want to know whether or not $\mathrm{I}\left(\underline{n}_A, 0\right) < \mathrm{I}\left(n_A, n_B\right)$ is feasible. Manipulating the inequality shows that this is the case when

$$\underline{n}_A \begin{cases} < n_A^{\max}\frac{\mathrm{I}(n_A,n_B)}{1-\mathrm{I}(n_A,n_B)} & \text{if } \mathrm{I}\left(n_A,n_B\right) < 1 \\ > n_A^{\max}\frac{\mathrm{I}(n_A,n_B)}{1-\mathrm{I}(n_A,n_B)} & \text{if } \mathrm{I}\left(n_A,n_B\right) > 1 \end{cases}.$$

Consider the first case. A sufficient condition for this case to hold is $\mathrm{I}\left(n_A, n_B\right) \in (1/2, 1)$, since $\underline{n}_A < \overline{n}_A$. The condition $\mathrm{I}\left(n_A, n_B\right) \in (1/2,1)$ can be made to hold by adjusting liquidity demand (level shift of both $\pi_A(n_A, 0)$ and $\pi_B(1, n_A)$) and the cost parameters c_A and c_B (level shifts of $\pi_A(n_A, 0)$ and $\pi_B(1, n_A)$ separately.)

Moreover, the following numeric example shows that the first case may hold even if $\mathrm{I}\left(n_A, n_B\right) < 1/2$. To this end, consider a case where $n_B = 1$ (without information sales). This is true in equilibrium if $\rho_B(1, n_A) = c_B$, i.e.

$$\frac{\sigma^2\sigma_y\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left(2\sigma^2+2\sigma_\epsilon^2\right)^2}\left[\frac{1}{4\left(\sigma^2+\sigma_\epsilon^2\right)} + \frac{n_A\left(\sigma^2+\sigma_\epsilon^2\right)}{\left[(n_A+1)\sigma^2+2\sigma_\epsilon^2\right]^2}\right]^{-1/2} = c_B,$$

or, in words, when the participation constraint of a single B-trader is binding. When the participation constraint of an A-trader is also binding,

$$\frac{\sigma^2\sigma_y\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left(\left(n_A+1\right)\sigma^2+2\sigma_\epsilon^2\right)^2}\left(\frac{n_A\left(\sigma^2+\sigma_\epsilon^2\right)}{\left[(n_A+1)\sigma^2+2\sigma_\epsilon^2\right]^2} + \frac{1}{4\left(\sigma^2+\sigma_\epsilon^2\right)}\right)^{-1/2} = c_A,$$

the structure (n_A, n_B) is an equilibrium.

Suppose these free-entry conditions hold (in the absence of sales), and consider a price $p_A < c_A$. This will increase n_A,.and in turn crowd out the B-trader. When this happens, the new free-entry condition for A-traders becomes

$$\frac{\sigma^2\sigma_y\left(\sigma^2+2\sigma_\epsilon^2\right)}{\left(\left(n_A+1\right)\sigma^2+2\sigma_\epsilon^2\right)^2}\left(\frac{n_A\left(\sigma^2+\sigma_\epsilon^2\right)}{\left[(n_A+1)\sigma^2+2\sigma_\epsilon^2\right]^2}\right)^{-1/2} = c_A.$$

I now compute the equilibrium information structure(s) for $\sigma^2 = 1$, $\sigma_y = 10$, $\sigma_\epsilon^2 = 10$, $c_A = 1/2$ and $p_A = 1/(2.1)$. (I use c_B as my degree of freedom.) Using the above conditions, I solve for the equilibrium number of A-traders without information sales,

$$\frac{210}{(n_A+21)^2}\left(\frac{11n_A}{(n_A+21)^2}+\frac{1}{44}\right)^{-1/2}=\frac{1}{2},$$

which yields $n_A = 12.236$. Similarly, the number of A-traders that enter once the B-trader has been crowded out can be computed via

$$\frac{210}{\frac{1}{2.1}\sqrt{11}}=(n_A+21)\sqrt{n_A}$$

as $\underline{n}_A = 14.238$. The B-trader will indeed drop out because

$$14 \leqslant \frac{20+1}{1}=21=\overline{n}_A,$$

that is, the price impact increases.

Price informativeness in this example drops from

$$\mathrm{I}(n_A,1)=\frac{12.236}{(12.236+1)+20}+\frac{1}{(1+1)+20}=0.413\,61$$

to

$$\mathrm{I}(\underline{n}_A,0)=\frac{14.238}{(14.238+1)+20}=0.404\,05.$$

Last but not least, note that $\mathrm{I}(n_A,1)<0.5$. ∎

Proof of Lemma 5

If $\mathrm{E}(K_I) \leq S+K_E$, any uninformative precommitment price preempts entry. That provided, it is clearly a Perfect Bayesian Equilibrium for all incumbent types to choose $p_A^I = p_A^m$. It is also straightforward to see that, from the incumbent's perspective, this is a Pareto-dominant equilibrium.

However, if $\mathrm{E}(K_I) > S+K_E$, a pooling price does not preempt entry. Therefore, some (of the more efficient) incumbent types have an incentive to reveal their type in order to deter the challenger. I first conjecture a Perfect Bayesian equilibrium such that all types below a cut-off type K_I^c preempt entry by setting a uniform price p_A^c and all types above K_I^* surrender the market. Incentive-compatibility requires that

$$n_A^*(p_A^c)\rho(n_A^*(p_A^c),n_B^*(p_A^c))-c_A-K_I<0 \quad \text{for all } K_I>K_I^c$$

and that

$$n_A^*(p_A^c)\rho(n_A^*(p_A^c),n_B^*(p_A^c))-c_A-K_I\geq 0 \quad \text{for all } K_I\leq K_I^c.$$

This trivially implies that p_A^* must satisfy

$$n_A^*(p_A^c)\rho(n_A^*(p_A^c),n_B^*(p_A^c))-c_A-K_I^c=0.$$

To deter entry, the cut-off value must further satisfy

$$\mathrm{E}(K_I\leq K_I^c)\leq K_I^+.$$

Since $\mathrm{E}(K_I) > S+K_E$ implies $K_I^+ < \mathrm{E}(K_I) < K_H$ and K_I is continuously distributed, there exists a unique $K_I^* \in [K_L, K_H)$ such that all $K_I^c < K_I^*$ satisfy this condition. Since p_A^c increases in the cut-off value K_I^c, the Pareto-dominant Perfect Bayesian equilibrium (from the incumbent's perspective) is to set the cut-off value as high as possible, that is, to $K_I^c = K_I^*$. To establish Pareto-dominance formally, it is easy to verify that all types above K_I^* earn zero profits in any Perfect Bayesian equilibrium, and that all types below K_I^* prefer a higher cut-off value not only because it preempts entry for more incumbent types but also because it increases the precommitment price and hence the profit of any incumbent type. If there is entry, price is set to incumbent's break-even price. ∎

Proof of Corollary 7

Lower S or K_E make it less likely that the information market is uncontestable ($\mathrm{E}(K_I)\leq S+K_E$). When the market is contestable, lower S or K_E decrease K_1^* and thereby also the equilibrium price. To see this, first note that K_I^+ increases in S and K_E (by definition: $K_I^+ = S+K_E$), that K_I^* increases in K_I^+ (by definition: $\mathrm{E}\left(K_I\leq K_I^*\right)=K_I^+$), and that the equilibrium price p_A^* increases in K_I^* (by definition: $n_A^*(p_A^*)\rho(n_A^*(p_A^*),n_B^*(p_A^*))=K_I^*+c_A$). By implication, K_1^* and p_A^* increase in S and K_E. ∎

7.1 Proof of Proposition 7

Each A-trader trades in both assets. Let α_{aA} denote A-traders' trading intensity when trading in asset a. By definition of the market makers' pricing functions,

$$p_1 = \lambda_1 \left(\sum_{i=1}^{n_A} x_{1A}(\tilde{s}_{iA}) + \sum_{l=1}^{n_B} x_B(\tilde{s}_{lB}) + \tilde{y} \right) \quad \text{and} \quad p_2 = \lambda_2 \left(\sum_{i=1}^{n_A} x_{2A}(\tilde{s}_{iA}) + \sum_{l=1}^{n_C} x_C(\tilde{s}_{lC}) + \tilde{y} \right)$$

which implies the following 'market index'

$$p_{\mathcal{M}} = \lambda_1 \left(\sum_{i=1}^{n_A} x_{1A}(\tilde{s}_{iA}) + \sum_{l=1}^{n_B} x_B(\tilde{s}_{lB}) + \tilde{y} \right) + \lambda_2 \left(\sum_{i=1}^{n_A} x_{2A}(\tilde{s}_{iA}) + \sum_{l=1}^{n_C} x_C(\tilde{s}_{lC}) + \tilde{y} \right).$$

Price variances are given by

$$\begin{aligned}
\text{Var}(p_1) &= (\lambda_1)^2 \text{Var}\left(\sum_{i=1}^{n_A} x_{1A}(\tilde{s}_{iA}) + \sum_{l=1}^{n_B} x_B(\tilde{s}_{lB}) + \tilde{y} \right) = (\lambda_1)^2 \text{Var}\left(\sum_{i=1}^{n_A} \alpha_{1A}\tilde{s}_{iA} + \sum_{l=1}^{n_B} \alpha_B \tilde{s}_{lB} + \tilde{y} \right) \\
&= (\lambda_1)^2 \left[\text{Var}\left(\sum_{i=1}^{n_A} \alpha_{1A}\left(\tilde{V}_A + \tilde{\epsilon}_i\right) \right) + \text{Var}\left(\alpha_B \sum_{l=1}^{n_B} \left(\tilde{V}_B + \tilde{\epsilon}_l\right) \right) + \sigma_y^2 \right] \\
&= (\lambda_1)^2 \left[(n_A\alpha_{1A})^2 \sigma^2 + (\alpha_{1A})^2 n_A \sigma_\epsilon^2 + (n_B\alpha_B)^2 \sigma^2 + (\alpha_B)^2 n_B \sigma_\epsilon^2 + \sigma_y^2 \right]
\end{aligned}$$

and, analogously,

$$\text{Var}(p_2) = (\lambda_2)^2 \left[(n_A\alpha_{2A})^2 \sigma^2 + (\alpha_{2A})^2 n_A \sigma_\epsilon^2 + (n_C\alpha_C)^2 \sigma^2 + (\alpha_C)^2 n_C \sigma_\epsilon^2 + \sigma_y^2 \right].$$

The variance of the market index is

$$\begin{aligned}
\text{Var}(p_{\mathcal{M}}) &= \text{Var}\left(\lambda_1 \sum_{i=1}^{n_A} x_{1A}(\tilde{s}_{iA}) + \lambda_2 \sum_{i=1}^{n_A} x_{2A}(\tilde{s}_{iA}) + (\lambda_1+\lambda_2)\tilde{y} + \lambda_1 \sum_{l=1}^{n_B} x_B(\tilde{s}_{lB}) + \lambda_2 \sum_{l=1}^{n_C} x_C(\tilde{s}_{lC}) \right) \\
&= \text{Var}\left(\lambda_1 \sum_{i=1}^{n_A} x_{1A}(\tilde{s}_{iA}) + \lambda_2 \sum_{i=1}^{n_A} x_{2A}(\tilde{s}_{iA}) \right) + \text{Var}\left[(\lambda_1+\lambda_2)\tilde{y}_2\right] \\
&\quad + (\lambda_1)^2 \left[(n_B\alpha_B)^2 \sigma^2 + (\alpha_B)^2 n_B \sigma_\epsilon^2 \right] + (\lambda_2)^2 \left[(n_C\alpha_C)^2 \sigma^2 + (\alpha_C)^2 n_C \sigma_\epsilon^2 \right] \\
&= (\lambda_1\alpha_{1A} + \lambda_2\alpha_{2A})^2 \left[(n_A)^2 \sigma^2 + n_A \sigma_\epsilon^2 \right] + (\lambda_1+\lambda_2)^2 \sigma_y^2 \\
&\quad + (\lambda_1)^2 \left[(n_B\alpha_B)^2 \sigma^2 + (\alpha_B)^2 n_B \sigma_\epsilon^2 \right] + (\lambda_2)^2 \left[(n_C\alpha_C)^2 \sigma^2 + (\alpha_C)^2 n_C \sigma_\epsilon^2 \right]
\end{aligned}$$

The covariances between individual asset prices and the market index are given by

$$\begin{aligned}
\text{Cov}(p_1, p_{\mathcal{M}}) &= \text{Cov}\left(\lambda_1 \left(\sum_{i=1}^{n_A} x_{1A}(\tilde{s}_{iA}) + \sum_{l=1}^{n_B} x_B(\tilde{s}_{lB}) + \tilde{y} \right), \lambda_1 \left(\sum_{i=1}^{n_A} x_{1A}(\tilde{s}_{iA}) + \sum_{l=1}^{n_B} x_B(\tilde{s}_{lB}) + \tilde{y} \right) + \lambda_2 \left(\sum_{i=1}^{n_A} x_{2A}(\tilde{s}_{iA}) + \tilde{y} \right) \right) \\
&= \text{Cov}\left(\lambda_1 \sum_{i=1}^{n_A} \alpha_{1A}\tilde{s}_{iA} + \lambda_1 \sum_{l=1}^{n_B} \alpha_B\tilde{s}_{lB} + \lambda_1\tilde{y}, (\lambda_1\alpha_{1A} + \lambda_2\alpha_{2A}) \sum_{i=1}^{n_A} \tilde{s}_{iA} + \lambda_1 \sum_{l=1}^{n_B} \alpha_B\tilde{s}_{lB} + (\lambda_1+\lambda_2)\tilde{y} \right) \\
&= \text{Cov}\left(\lambda_1 \sum_{i=1}^{n_A} \alpha_{1A}\tilde{s}_{iA} + \lambda_1 \sum_{l=1}^{n_B} \alpha_B\tilde{s}_{lB} + \lambda_1\tilde{y}, (\lambda_1\alpha_{1A} + \lambda_2\alpha_{2A}) \sum_{i=1}^{n_A} \tilde{s}_{iA} \right) + \\
&\quad \text{Cov}\left(\lambda_1 \sum_{i=1}^{n_A} \alpha_{1A}\tilde{s}_{iA} + \lambda_1 \sum_{l=1}^{n_B} \alpha_B\tilde{s}_{lB} + \lambda_1\tilde{y}, \lambda_1 \sum_{l=1}^{n_B} \alpha_B\tilde{s}_{lB} \right) + \\
&\quad \text{Cov}\left(\lambda_1 \sum_{i=1}^{n_A} \alpha_{1A}\tilde{s}_{iA} + \lambda_1 \sum_{l=1}^{n_B} \alpha_B\tilde{s}_{lB} + \lambda_1\tilde{y}, (\lambda_1+\lambda_2)\tilde{y} \right) \\
&= (\lambda_1\alpha_{1A})(\lambda_1\alpha_{1A} + \lambda_2\alpha_{2A}) \left[(n_A)^2 \sigma^2 + n_A\sigma_\epsilon^2 \right] + (\lambda_1\alpha_B)^2 \left[(n_B)^2 \sigma^2 + n_B\sigma_\epsilon^2 \right] + (\lambda_1)(\lambda_1+\lambda_2)\sigma_y^2
\end{aligned}$$

and, similarly,

$$\text{Cov}(p_2, p_{\mathcal{M}}) = (\lambda_2\alpha_{2A})(\lambda_1\alpha_{1A} + \lambda_2\alpha_{2A}) \left[(n_A)^2 \sigma^2 + n_A\sigma_\epsilon^2 \right] + (\lambda_2\alpha_C)^2 \left[(n_C)^2 \sigma^2 + n_C\sigma_\epsilon^2 \right] + (\lambda_2)(\lambda_1+\lambda_2)\sigma_y^2.$$

The correlation coefficients are thus

$$\rho_{1\mathcal{M}} = \frac{1}{\sqrt{(\lambda_1)^2\left[(n_A\alpha_{1A})^2\sigma^2+(\alpha_{1A})^2 n_A\sigma_\epsilon^2+(n_B\alpha_B)^2\sigma^2+(\alpha_B)^2 n_B\sigma_\epsilon^2+\sigma_y^2\right]}}$$
$$\frac{(\lambda_1\alpha_{1A})(\lambda_1\alpha_{1A}+\lambda_2\alpha_{2A})\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]+(\lambda_1\alpha_B)^2\left[(n_B)^2\sigma^2+n_B\sigma_\epsilon^2\right]+(\lambda_1)(\lambda_1+\lambda_2)\sigma_y^2}{\sqrt{(\lambda_1\alpha_{1A}+\lambda_2\alpha_{2A})^2\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]+(\lambda_1+\lambda_2)^2\sigma_y^2+(\lambda_1)^2\left[(n_B\alpha_B)^2\sigma^2+(\alpha_B)^2 n_B\sigma_\epsilon^2\right]+(\lambda_2)^2\left[(n_C\alpha_C)^2\sigma^2+(\alpha_C)^2 n_C\sigma_\epsilon^2\right]}}$$

and

$$\rho_{2\mathcal{M}} = \frac{1}{\sqrt{(\lambda_1)^2\left[(n_A\alpha_{1A})^2\sigma^2+(\alpha_{1A})^2 n_A\sigma_\epsilon^2+(n_B\alpha_B)^2\sigma^2+(\alpha_B)^2 n_B\sigma_\epsilon^2+\sigma_y^2\right]}}$$
$$\frac{(\lambda_2\alpha_{2A})(\lambda_1\alpha_{1A}+\lambda_2\alpha_{2A})\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]+(\lambda_2\alpha_C)^2\left[(n_C)^2\sigma^2+n_C\sigma_\epsilon^2\right]+(\lambda_2)(\lambda_1+\lambda_2)\sigma_y^2}{\sqrt{(\lambda_1\alpha_{1A}+\lambda_2\alpha_{2A})^2\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]+(\lambda_1)^2\left[(n_B\alpha_B)^2\sigma^2+(\alpha_B)^2 n_B\sigma_\epsilon^2\right]+(\lambda_2)^2\left[(n_C\alpha_C)^2\sigma^2+(\alpha_C)^2 n_C\sigma_\epsilon^2\right]+(\lambda_1+\lambda_2)^2\sigma_y^2}}.$$

Simple inspection shows that these correlation coefficients must be smaller than 1 as long as $(n_B, n_C) \neq (0,0)$. This is intuitive. For instance, if $n_c > 0$, the price of asset 1 is independent of the C-factor, whereas the market index is not.

By contrast, consider the case where the monopolist engages in predatory selling and crowds out information about the idiosyncratic signals ($n_B = n_C = 0$). In this case, A-traders face no rival trader group in either asset market. Using $\alpha_{1A} = \alpha_{2A} = \alpha_A$, the correlation coefficient then becomes

$$\begin{aligned}
\rho_{1\mathcal{M}} &= \frac{(\lambda_1\alpha_A)(\lambda_1\alpha_A+\lambda_2\alpha_A)\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]+(\lambda_1)(\lambda_1+\lambda_2)\sigma_y^2}{\sqrt{\left\{(\lambda_1\alpha_A)^2\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]+(\lambda_1)^2\sigma_y^2\right\}\left\{(\lambda_1\alpha_A+\lambda_2\alpha_A)^2\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]+(\lambda_1+\lambda_2)^2\sigma_y^2\right\}}}\\
&= \frac{(\alpha_A)^2(\lambda_1)(\lambda_1+\lambda_2)\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]+(\lambda_1)(\lambda_1+\lambda_2)\sigma_y^2}{\sqrt{(\alpha_A)^4(\lambda_1)^2(\lambda_1+\lambda_2)^2\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]^2+2(\alpha_A)^2(\lambda_1)^2(\lambda_1+\lambda_2)^2\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]\sigma_y^2+(\lambda_1)^2(\lambda_1+\lambda_2)^2\sigma_y^4}}\\
&= \frac{(\alpha_A)^2\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]+\sigma_y^2}{\sqrt{(\alpha_A)^4\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]^2+2(\alpha_A)^2\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]\sigma_y^2+\sigma_y^4}} = \frac{(\alpha_A)^2\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]+\sigma_y^2}{\sqrt{\left((\alpha_A)^2\left[(n_A)^2\sigma^2+n_A\sigma_\epsilon^2\right]+\sigma_y^2\right)^2}} = 1.
\end{aligned}$$

That, $n_A = n_B > 0$ is more likely to occur for lower S_1, K_E or S_2 follows from Corollary 7 and the analysis in Sections 3 and 4.

Table to Figure 1

The press freedom ranking is based on the 2002 worldwide press freedom index published on the website of Reporters without Borders (http:\\www.rsf.org). The comovement ranking is based on the R^2-scores reported in the second part of Fig. 4 in Morck et al. (2000).

Country	Press Freedom (Index)	Press Freedom (Rank)	Comovement (Rank)
China	97	40	39
Singapore	56	39	26
Pakistan	44,67	38	22
Columbia	40,83	37	30
Malaysia	37,83	36	37
Turkey	33,5	35	36
Philippines	29	34	20
India	26,5	33	25
Mexico	24,75	32	35
Thailand	22,75	31	33
Indonesia	20	30	14
Brazil	18,75	29	19
Czech	11,25	28	24
Italy	11	27	23
Korea	10,5	26	21
Peru	9,5	25	34
Taiwan	9	24	38
Poland	7,75	23	40
Spain	7,75	22	28
South Africa	7,5	21	29
Japan	7,5	20	32
Austria	7,5	19	10
Chile	6,5	18	31
United Kingdom	6	17	4
Greece	5	16	27
Hong Kong	4,83	15	18
US	4,75	14	1
Belgium	3,5	13	17
Australia	3,5	12	5
New Zealand	3,5	11	6
France	3,25	10	8
Denmark	3	9	9
Sweden	1,5	8	15
Portugal	1,5	7	7
Germany	1,5	6	12
Ireland	1	5	2
Canada	0,75	4	3
Finland	0,5	3	16
Norway	0,5	2	13
Holland	0,5	1	11

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