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The Incentive to Sell Financial Market Information*

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Investment advisory firms and brokerage firms hire analysts to uncover profitable securities investment opportunities. Then these firms sell the information (either directly or indirectly) to others. Why? Given that the information has value, why do these firms not keep the information to themselves and trade solely for their own accounts? Because of competition, information is more valuable when fewer people trade on the information. This paper shows that selling information is a strategic response by competing informed traders. Specifically, it is a means for informed traders to commit to trade aggressively, thereby inducing other informed traders to trade less aggressively. *Journal of Economic Literature* Classification Numbers: G10, D82.

I. INTRODUCTION

Investment advisory firms and brokerage firms hire research analysts to uncover profitable securities investment opportunities. Then these firms sell the information (either directly or indirectly) to others. Why? Given that the information has value, and why else do people pay for it, why do these firms not keep the information to themselves and trade solely for their own accounts?[1] Because of competition, information is more valu-

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[1] Evidence that one such service, the Value Line Investment Survey, does contain information regarding future stock returns is found by, among others, Copeland and Mayers (1982) and Stickel (1985). These studies find a positive relation between the Value Line rankings and future stock price performance. Affleck-Graves and Mendenhall (1992), however, present evidence that this apparent forecasting power of Value Line might instead be a manifestation of the so-called post-earnings-announcement drift whereby stock price performance is positively related to surprises in earnings announcements. Womack (1994) finds evidence that brokers' recommendations contain information regarding future stock returns.

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able when fewer people trade on the information. As shown by Kyle (1984) and Admati and Pfleiderer (1988a), the expected trading profit of an individual informed trader and the aggregate expected trading profit of informed traders decreases as the number of informed traders increases.

This paper develops the explanation that selling information is a strategic response by competing informed traders. Specifically, it is a means for an informed trader to commit to trade aggressively, thereby inducing other informed traders to trade less aggressively. Consider the following illustration. Suppose there are two informed traders in a market. The traders have the same information and without commitment each has an expected trading profit of 50. Suppose, now, trader 1 commits to trade very aggressively. If this commitment is binding, trader 2 will be induced to trade less aggressively since the marginal profitability of his trades is now lower. If trader 1's commitment is successful, then perhaps his expected trading profit increases to 60 while trader 2's expected profit decreases to 30. Though the total expected trading profit has decreased (from 100 to 90), trader 1 captures a larger share of the total. How, though, does trader 1 make such a commitment? Selling his information is a way to do it. Suppose trader 1 sells his information to trader 3. There are now three informed traders. Since all three traders have the same information, they expect the same trading profit, say 30 per trader. If trader 3 pays 30 for the information, then trader 1 has increased his expected profit from 50 to 60. By selling his information, trader 1 has lowered the total expected trading profit but captured a greater share of this total.

The central result of the paper is that informed traders would sell their information to others. In addition, we derive the following results. The number of people to whom a seller sells his information is increasing in: (i) the variability of the value of the security being traded; (ii) the precision of the seller's information; and (iii) the precision of a competing seller's information. Further, information sellers may have higher expected profits if they produce lower quality information, and cross-sectionally, lower quality information may sell for a higher price.

Another possible explanation for information selling is risk aversion. Trading securities is risky and risk-averse individuals may be better off selling information for a fixed fee rather than just trading on it. This spreads the risk associated with securities research across the information seller and the buyers. This argument is inadequate, however, as an explanation for why investment advisory firms and brokerage firms sell information, because, as shown by Admati and Pfleiderer (1988b), a more efficient way to share risk is to set up a mutual fund. The reason is as follows. The expected profit from trading on information is inversely related to the number of individuals who trade on it. With a mutual fund, competition among individual traders is minimized. One individual does the trading while many share the profits. The commitment effect of information selling that we study is absent in Admati and Pfleiderer's analysis. This is because their information seller is a monopolist and therefore is not required to sell his information in order to secure a larger share of the trading profit. Being a monopolist, he already earns all of the trading profits. Instead, information selling is driven solely by risk aversion. In our analysis, risk aversion plays no role; prospective sellers and buyers of information are assumed to be risk neutral.

Vishny (1985) studies a brokerage firm's incentive to sell (or disclose) speculative information for the purpose of increasing the liquidity of the market. He considers a setting in which liquidity traders trade more as the market becomes more liquid. If a brokerage firm with private information earns sufficient revenues from the increase in the liquidity traders' trading commissions, then it is profitable to sell their information to others (even though the information is devalued).[2]

Admati and Pfleiderer (1990) also compare the direct sale of information to the establishment of a mutual fund. They show that as long as mutual fund investors can be charged a fixed fee plus a per share fee, then establishing a mutual fund is more profitable than selling the information directly. In this paper, unlike their 1988b paper, Admati and Pfleiderer do not model the incentive to sell the information. It is simply assumed that the information producer cannot trade on the information. Kane and Marks (1990) compare the direct sale of information to the establishment of a mutual fund and argue that if individual investors and mutual funds face borrowing constraints, then a direct sale is preferred. Their analysis, however, does not consider the effect of information selling on the determination of asset prices, and thus ignores the devaluation of information that results from information selling.

Though not addressing the issue of why people have the incentive to sell their information, a number of papers have studied other important aspects of information selling. Admati and Pfleiderer (1986) study the possibility of adding noise to signals before selling them. They show that this can be profitable because it limits the amount of information that is revealed by the market price and thus limits the devaluation of the information. We briefly consider this strategy. Though the incentive to do so differs, in our model too, information sellers might choose to add noise to the signals that they sell. Allen (1990) studies the problem of credibility in information selling: how contracts are structured when potential buyers do not know if the information seller really has any useful information. We do not address the issue of credibility; we assume that potential

[2] Bushman and Indjejikian (1993) also consider a setting in which public information disclosure increases liquidity trading and market liquidity. They show that if an informed trader releases some of his information, the resulting increase in liquidity can lead to higher expected trading profits.

buyers know the quality of the information that they are buying. Brennan and Chordia (1991) study information selling by brokers and compare charging customers a fixed fee to charging customers through brokerage commissions. They show that brokerage commissions are a means for the customer to share the risk with the (risk-neutral) broker. This is because customers will trade more shares with more valuable information, and so commissions induce higher (lower) payments for more (less) valuable information. In our analysis, information sellers charge a fixed fee for information.

In independent research, Sabino (1993) and Shin (1993) study the same incentive to sell information as in our paper. The modeling difference is in the timing: in our paper, the timing is (i) the market maker chooses a pricing rule; (ii) information sellers choose how widely to sell their information; and (iii) traders trade. This timing focuses the analysis solely on the competitive effects of information selling; information selling has no direct effect on market liquidity. In both Sabino and Shin, the timing of the first two stages is reversed with the market maker choosing a pricing rule after the information sellers choose how widely to sell their information. Their timing introduces a secondary effect of information selling; like Vishny (1985), as information is sold more widely, the market becomes more liquid. This liquidity effect is what accounts for the difference in the results between our paper and theirs. An advantage of our approach is that it simplifies the analysis; for instance, closed-form solutions for the number of people who buy information can be derived. Note, though, that our model is equivalent to one in which the timing is the same as in Sabino and Shin but the market maker does not directly observe information sellers' choices of how widely to sell their information. Instead, a market maker must deduce these choices. We believe this is the more natural way to think about the problem. In practice, a market maker does not directly observe the number of clients of investment advisory or brokerage firms. Another application where a market maker does not directly observe how widely information is sold is that of illegal insider trading. In this case, an informed party must transmit the information covertly.

Section II analyzes the value of committing to trade aggressively and demonstrates that selling information is a means of establishing this commitment. This analysis assumes but one information seller. Section III considers the case with two information sellers. Section IV concludes.

II. COMMITTING TO TRADE AGGRESSIVELY AND SELLING INFORMATION

In this section we compare three scenarios: (i) a market with multiple informed traders, none of whom can sell their information or commit to trade with a given intensity; (ii) a market with multiple informed traders, one of whom can commit to trade with a given intensity; and (iii) a market with multiple informed traders, one of whom can sell his information. We show that in this setting, the ability to sell information and the ability to commit to trade with a given intensity lead to equivalent outcomes, increasing the expected profit of the informed trader who sells his information (or commits). This increase comes at the expense of the other informed traders.

The modeling of the securities market follows the noncompetitive model of Kyle (1984, 1985) and Admati and Pfleiderer (1988a). A security worth $\mu + \theta$ is traded, where μ is a known constant and θ is a random variable. Informed traders and liquidity traders submit market orders to a competitive, risk-neutral market maker who takes the position that balances supply and demand. The market maker sets the share price equal to the expected value of a share conditional on the order flow.

There are $k > 1$ risk-neutral informed traders who each observe θ. Informed trader i trades x_i shares. Liquidity traders' share demand, z, is exogenous. Assume that θ and z are independent, normally distributed random variables with means 0 and variances $1/h$ and $1/\phi$, respectively. Let ω denote the net order flow, $\omega = \sum x_i + z$. Let $P(\omega)$ denote the market maker's pricing rule; P specifies the price as a function of the order flow. For a share price of p, a trader who buys x_i shares earns a trading profit of $x_i(\mu + \theta - p)$.

The Nash equilibrium for this model consists of trading strategies for the informed traders and a pricing rule for the market maker such that (i) each informed trader's strategy maximizes his expected trading profit taking the other traders' strategies and the pricing rule as given; and (ii) the pricing rule satisfies $P(\omega) = \mu + E[\tilde{\theta} \mid \tilde{\omega} = \omega]$ taking the trading strategies as given. Informed traders take the effect of their trades on price into account. They take the pricing rule, not the price as given. The equilibrium for this model has been derived by Kyle (1984) and Admati and Pfleiderer (1988a) and is given in Lemma 1 (a proof is in both papers).

LEMMA 1. *There is a unique equilibrium in which the informed traders' strategies are linear functions, $\beta(k)\theta$, and the pricing rule is linear, $P(\omega) = \mu + \lambda(k)\omega$, where*

$$\beta(k) = \frac{1}{(k+1)\lambda(k)} \tag{1}$$

and

$$\lambda(k) = \frac{1}{k+1}\sqrt{\frac{k\phi}{h}}. \tag{2}$$

In this equilibrium, an informed trader's expected profit equals

$$\begin{aligned}\pi(k) &= E[\beta(k)\tilde{\theta}(\tilde{\theta} - \lambda(k)(k\beta(k)\tilde{\theta} + \tilde{z}))] \\ &= \frac{1}{(k+1)^2 h\lambda(k)} \\ &= \frac{1}{k+1}\sqrt{\frac{1}{kh\phi}},\end{aligned} \tag{3}$$

where the second equality follows from substituting in (1) and taking the expectation, and the third equality follows from substituting in (2).

Now consider the case with commitment. Specifically, suppose informed trader 1 can publicly commit to follow a particular trading strategy. How will the other $k - 1$ informed traders respond? Assume that the timing is as follows: first the market maker announces a pricing rule, $\mu + \lambda^c\omega$, then trader 1 commits to a trading strategy, after which traders observe θ and submit their trades. This timing ensures that trader 1's commitment has no direct effect on the market maker's pricing rule; the pricing rule is announced first. In moving first, though, the market maker anticipates trader 1's choice and chooses the zero-expected-profit pricing rule accordingly.

Trader 1 is a Stackelberg leader in this commitment case. Taking λ^c and trader 1's trade, x_1, as given, the equilibrium trading strategy of traders 2 through k is determined as follows. The expected trading profit of informed trader $i \neq 1$ equals

$$\begin{aligned}&E[x_i(\tilde{\theta} - \lambda^c(x_1 + \sum_{j\neq 1,i} x_j + x_i + \tilde{z})) \mid \tilde{\theta} = \theta] \\ &\quad = x_i(\theta - \lambda^c(x_1 + \sum_{j\neq 1,i} x_j + x_i)).\end{aligned} \tag{4}$$

The first-order condition for an optimum for trader i is

$$x_i = \frac{\theta - \lambda^c(x_1 + \sum_{j=2}^{k} x_j)}{\lambda^c}. \tag{5}$$

The right-hand side of (5) is independent of i, implying that $x_2 = x_3 = \cdots = x_k$, with

$$x_i = \frac{\theta - \lambda^c x_1}{k\lambda^c}. \tag{6}$$

The more aggressively trader 1 commits to trade, the less aggressively do others trade; that is, x_i is decreasing in x_1. This is because larger trades by trader 1 reduce the marginal profitability of trading for the others. This is the advantage of commitment for trader 1. By inducing others to trade less aggressively, trader 1 earns higher expected trading profits. Specifically, given (6), trader 1's expected trading profit with commitment as a function of a trade x_1 and a realization $\tilde{\theta} = \theta$ equals

$$E[x_1(\tilde{\theta} - \lambda^c(x_1 + (k-1)\frac{\tilde{\theta} - \lambda^c x_1}{k\lambda^c} + \tilde{z})) \mid \tilde{\theta} = \theta] = \frac{x_1(\theta - \lambda^c x_1)}{k}. \tag{7}$$

Proposition 1. *With commitment by trader* 1, *the trading strategy of trader* 1 *is* $k\beta(2k-1)\theta$, *the trading strategy of traders* 2 *through* k *is* $\beta(2k-1)\theta$, *and the pricing rule is* $\mu + \lambda(2k-1)\omega$.

Proof. Taking λ^c as given, the value of x_1 that maximizes (7) is given by $\theta/2\lambda^c$. Substituting this into (6) yields the strategy of traders 2 through k, $\theta/2k\lambda^c$. These trading strategies imply an order flow of $\omega = \theta/2\lambda^c + (k-1)\theta/2k\lambda^c + z = (2k-1)\theta/2k\lambda^c + z$. Satisfying $\lambda^c\omega = E[\tilde{\theta} \mid \tilde{\omega} = \omega]$ requires $\lambda^c = \text{cov}(\tilde{\theta}, \tilde{\omega})/\text{var}(\tilde{\omega})$. Substituting in for ω and solving for λ^c yields $\lambda^c = \lambda(2k-1)$. Substituting in for λ^c in traders' strategies yields a strategy for trader 1 of $k\beta(2k-1)\theta$ and a strategy for traders 2 through k of $\beta(2k-1)\theta$. ∎

With commitment, trader 1 trades more aggressively and the other $k-1$ informed traders trade less aggressively, $k\beta(2k-1) > \beta(k) > \beta(2k-1)$. In effect, trader 1 trades as aggressively as k traders. Adding in the other $k-1$ traders makes the market with commitment like a market without commitment and $2k-1$ traders. In the aggregate, trading is more aggressive, $k\beta(2k-1) + (k-1)\beta(2k-1) = (2k-1)\beta(2k-1) > k\beta(k)$, which implies that the market is more liquid, $\lambda(2k-1) < \lambda(k)$. Trader 1's profit with commitment equals k times the profit in the no-commitment case when there are $2k-1$ traders, $k\pi(2k-1)$. The expected profit of the other $k-1$ informed traders equals the expected profit in the no-commitment case when there are $2k-1$ traders, $\pi(2k-1)$. With commitment, trader 1's expected profit is higher and the other $k-1$ informed traders' expected profits are lower, $k\pi(2k-1) > \pi(k) > \pi(2k-1)$.

Trader 1 is better off with commitment. While aggregate expected trading profits are lower, $k\pi(2k-1) + (k-1)\pi(2k-1) = (2k-1)\pi(2k-1) < k\pi(k)$, trader 1 captures a larger share. Trader 1 has extracted expected trading profits from the other $k - 1$ informed traders. How, though, does trader 1 undertake such a commitment?[3]

Selling information is a way for trader 1 to make this commitment. Suppose trader 1 (truthfully) sells the information, θ, to n otherwise uninformed risk-neutral individuals who cannot resell the information. Then there are $n + k$ informed traders all of whom trade independently.[4] Assume that the timing of events is as follows: first, the market maker announces a pricing rule, $\mu + \lambda_1^s\omega$, then trader 1 chooses n, and then the $n + k$ traders observe θ and submit their trades. As in the commitment case, this timing ensures that trader 1's information-selling decision does not directly affect the market maker's pricing rule. Also as in the commitment case, the market maker's choice of λ_1^s anticipates trader 1's choice of n. This timing focuses the analysis solely on the competitive effects of information selling.

Taking λ_1^s as given, $n + k$ informed traders would each have an expected trading profit of

$$\frac{1}{(n + k + 1)^2 h\lambda_1^s}. \tag{8}$$

This follows from the second equality of (3), replacing $\lambda(k)$ with λ_1^s and replacing k with $n + k$.

The n purchasers of information all expect the same trading profit, given by (8). Thus the market-clearing price for the information is given by (8). Trader 1's total revenue consists of his personal trading profit plus his revenue from selling information. This total revenue equals an individual's expected trading profit, (8), multiplied by $n + 1$,

$$\frac{n + 1}{(n + k + 1)^2 h\lambda_1^s}. \tag{9}$$

[3] Kyle and Wang (1993) study the effects of overconfident informed traders (those who believe that their information is more informative than it really is) in a Kyle-type model. An overconfident trader trades more aggressively than he would otherwise, and induces a rational informed trader to trade less aggressively. Depending on the extent of the overconfidence, this can lead to higher expected trading profits for an overconfident trader and lower expected trading profits for a rational trader. These results are similar to our commitment results.

[4] We have assumed that trader 1 sells information as well as trades for his own account. In this model it would not matter if trader 1 committed to only sell information and not trade for himself. He would just sell the information to one additional person. Nothing else changes. A commitment not to trade by an information seller is more interesting in a context in which the seller might sell misinformation.

PROPOSITION 2. *Given information selling by trader 1, trader 1 will sell his information to $k - 1$ individuals. The equilibrium trading strategy of the $2k - 1$ informed traders is $\beta(2k - 1)\theta$ and the pricing rule is $\mu + \lambda(2k - 1)\omega$.*

Proof. Taking λ_1^s as given, trader 1 maximizes his total expected revenue, given by (9), by choosing $n = k - 1$. Thus, there will be a total of $2k - 1$ informed traders. The specification of the trading strategy of the $2k - 1$ informed traders and the market maker's pricing rule follow from Lemma 1. ■

The expected trading profit of each trader equals $\pi(2k - 1)$. By selling the information to $k - 1$ individuals, trader 1 duplicates the outcome of the commitment case. Specifically, as a group, trader 1 and the $k - 1$ individuals that buy the information trade as aggressively as did trader 1 in the commitment case; their aggregate trading strategy is $k\beta(2k - 1)\theta$. Further, the other $k - 1$ informed traders trade as aggressively as they did in the commitment case. Finally, market liquidity is unchanged. It follows that total expected revenues are the same for trader 1.

Trader 1 is better off by selling information, which is the same as commitment. Of course, other informed traders have the incentive to sell information too. We now consider a case with two information sellers.

III. TWO INFORMATION SELLERS

Assume that there are two informed traders. Trader i, $i = 1, 2$, observes the noisy signal $\theta + \varepsilon_i$, where ε_i is normally distributed with mean 0 and variance $1/\tau_i$. For simplicity assume that ε_i is independent of ε_j $(j \neq i)$, θ, and z. Both informed traders can sell their information, with trader i selling the information $\theta + \varepsilon_i$ to n_i otherwise uninformed risk-neutral individuals who cannot resell the information. Then there are a total of $n_1 + n_2 + 2$ informed traders, with $n_i + 1$ traders having observed $\theta + \varepsilon_i$. Assume that the timing is as follows: first, the market maker announces a pricing rule, $\mu + \lambda_2^s\omega$, then traders 1 and 2 simultaneously choose n_1 and n_2 respectively, and then the $n_1 + n_2 + 2$ traders observe their information and submit their trades. As in the case with one information seller, this timing focuses the analysis solely on the competitive effects of information selling. As mentioned in the Introduction, Sabino (1993) and Shin (1993) both reverse the timing; information sellers choose how many people they will sell to and then the market maker chooses a pricing rule. In their analyses, information sellers take account of their effect on the market maker's choice of pricing rules as well as on other traders' trading strategies.

LEMMA 2. *Taking n_1 and n_2 as given, there is a unique equilibrium in which the informed traders' strategies and the market maker's pricing rule are linear functions. The $n_i + 1$ traders who observe $\theta + \varepsilon_i$ follow the trading strategy $\beta_i^s(\theta + \varepsilon_i)$ and the pricing rule is $P(\omega) = \mu + \lambda_2^s\omega$,* where

$$\beta_1^s = \frac{t_1\left(1 - t_2\dfrac{n_2+1}{n_2+2}\right)}{(n_1+2)\left(1 - t_1t_2\dfrac{n_1+1}{n_1+2}\dfrac{n_2+1}{n_2+2}\right)\lambda_2^s} \tag{10}$$

and

$$\beta_2^s = \frac{t_2\left(1 - t_1\dfrac{n_1+1}{n_1+2}\right)}{(n_2+2)\left(1 - t_1t_2\dfrac{n_1+1}{n_1+2}\dfrac{n_2+1}{n_2+2}\right)\lambda_2^s} \tag{11}$$

and

$$\lambda_2^s = \phi^{1/2}\sqrt{\begin{aligned}&\frac{t_1N_1(1-t_2N_2)+t_2N_2(1-t_1N_1)}{h(1-t_1t_2N_1N_2)} - \frac{(t_1N_1(1-t_2N_2)+t_2N_2(1-t_1N_1))^2}{h(1-t_1t_2N_1N_2)^2}\\ &- \frac{(t_1N_1(1-t_2N_2))^2}{\tau_1(1-t_1t_2N_1N_2)^2} - \frac{(t_2N_2(1-t_1N_1))^2}{\tau_2(1-t_1t_2N_1N_2)^2}\end{aligned}}, \tag{12}$$

where $t_i = \tau_i/(\tau_i + h)$ and $N_i = (n_i + 1)/(n_i + 2)$.

Proof. See Appendix.

As before, the market-clearing price of information equals the expected trading profit given the information. Trader 1's total expected revenue equals his expected personal trading profit plus his revenue from selling information to n_1 individuals. Thus, trader 1's total expected revenue equals an individual's expected trading profit multiplied by $n_1 + 1$. This is given by

$$\begin{aligned}\Pi_1(n_1, n_2, t_1, t_2) &= (n_1+1)E[\beta_1^s(\tilde\theta + \tilde\varepsilon_1)(\tilde\theta - \lambda_2^s((n_1+1)\beta_1^s(\tilde\theta+\tilde\varepsilon_1)\\ &\quad + (n_2+1)\beta_2^s(\tilde\theta+\tilde\varepsilon_2) + \tilde z))]\\ &= \frac{t_1\left(1 - t_2\dfrac{n_2+1}{n_2+2}\right)^2\dfrac{n_1+1}{(n_1+2)^2}}{\lambda_2^s h\left(1 - t_1t_2\dfrac{n_1+1}{n_1+2}\dfrac{n_2+1}{n_2+2}\right)^2},\end{aligned} \tag{13}$$

where the second equality follows from substituting in (10) and (11), taking the expectation, and simplifying. Similarly, trader 2's total expected revenue equals

$$\Pi_2(n_1, n_2, t_1, t_2) = \frac{t_2\left(1 - t_1 \frac{n_1 + 1}{n_1 + 2}\right)^2 \frac{n_2 + 1}{(n_2 + 2)^2}}{\lambda_2^s h\left(1 - t_1 t_2 \frac{n_1 + 1}{n_1 + 2} \frac{n_2 + 1}{n_2 + 2}\right)^2}. \tag{14}$$

We now solve for the Nash equilibrium determining the number of individuals to whom traders 1 and 2 will sell their information. Taking λ_2^s and n_2 as given, trader 1 maximizes his total expected revenue, given by (13), by choosing

$$n_1 = \frac{(n_2 + 1)t_1 t_2}{(n_2 + 1)(1 - t_1 t_2) + 1}. \tag{15}$$

Similarly, taking λ_2^s and n_1 as given, trader 2 maximizes his total expected revenue, given by (14), by choosing

$$n_2 = \frac{(n_1 + 1)t_1 t_2}{(n_1 + 1)(1 - t_1 t_2) + 1}. \tag{16}$$

Note that the optimal choice of traders 1 and 2 depends on the precision of their information only through $t_1 t_2$, and $t_1 t_2 = \text{corr}(\theta + \varepsilon_1, \theta + \varepsilon_2)^2$.

PROPOSITION 3. *With information selling by traders* 1 *and* 2, *both sell their information to the same number of individuals*, $n_1 = n_2 = n^*$, where

$$n^* = \left(1 - \frac{\tau_1}{\tau_1 + h} \frac{\tau_2}{\tau_2 + h}\right)^{-1/2} - 1. \tag{17}$$

Proof. Solving (15) and (16) for n_1 and n_2 and substituting in for $t_i = \tau_i/(\tau_i + h)$ yields (17). ■

Traders 1 and 2 sell their information to the same number of individuals, though if $\tau_1 \neq \tau_2$, the prices that they charge will differ; information of a higher precision sells for a higher price. The more precise the information of one trader, the more widely will both traders sell their information. Moreover, the more variable is the underlying security, the more widely sold is the information; that is, n^* is increasing in τ_1 and τ_2 and decreasing in h.[5] In Sabino (1993) and Shin (1993), competing information

[5] The specification of n^* does not account for the integer constraint associated with the number of individuals who can purchase the information. Accounting for this constraint does not change the nature of the results.

sellers sell their information to different numbers of traders; the seller with higher-quality information sells to more traders. This difference in results arises because while the competitive effects of information selling (the only effect entering our analysis) depends only on the correlation between the sellers' signals, the liquidity effect of information selling depends on the individual precision of the sellers' signals.

With one information seller, selling information led to a higher total expected profit. This is not the case with two information sellers. Suppose sellers have signals of equal precision. With or without information selling, traders 1 and 2 evenly split the total trading profit in the market. This total is lower, though, with information selling. This is because there are more people trading on the same information, and the greater competition reduces total trading profits. So traders 1 and 2 would be better off if each could commit to not sell their information. To see this, note that the total expected trading profit of informed traders equals the total expected loss of liquidity traders. Given a pricing rule $\mu + \lambda\omega$, and letting $\tilde{x}$ denote the net order flow from the informed traders, the liquidity traders' expected trading losses equal $E[\tilde{z}(\lambda(\tilde{x} + \tilde{z}) - \tilde{\theta})] = \lambda/\phi$. A higher λ indicates a less liquid market in which liquidity traders' losses, and informed traders' profits, are higher. With information selling, λ is lower. That is, it is straightforward to show that λ_2^s evaluated at $\tau_1 = \tau_2$ and $n_i = n^*$ is lower than λ_2^s evaluated at $\tau_1 = \tau_2$ and $n_i = 0$.

Figure 1 illustrates traders' total expected profits with and without information selling for cases in which traders 1 and 2 have signals of

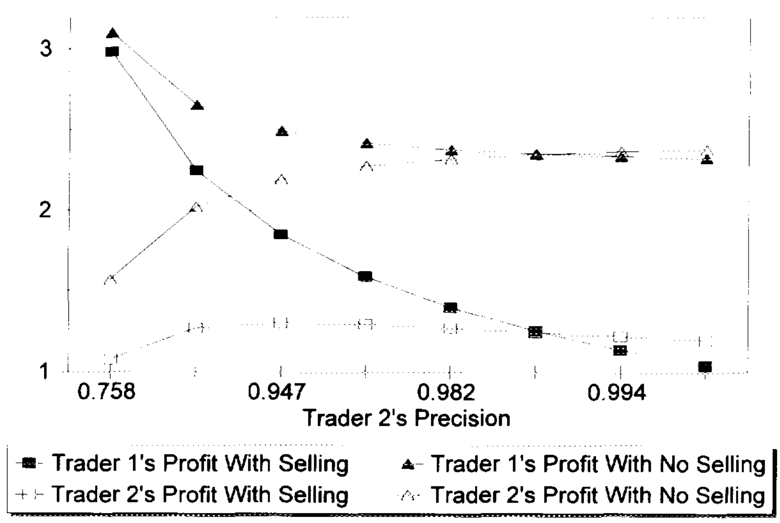

FIG. 1. Total profits.

different precision. For this example, $h = 1$, $t_1 = \tau_1/(\tau_1 + h) = 0.99$, and $\phi = 0.01$. The figure plots the two traders' total profits for values of $t_2 = \tau_2/(\tau_2 + h)$ ranging from 0.758 to 0.998. The variation in t_2 corresponds to equilibria in which the number of individuals to whom information is sold ranges from 1 to 8 (the pairs of t_1 and t_2 considered all imply integer values of n^*). As in the case in which the two traders had signals with the same precision, profits are lower with information selling. We conjecture, but have been unable to prove, that this result holds for arbitrary values of t_1 and t_2. The prisoner's dilemma aspect of information selling appears to dominate any relative advantage of selling that one seller might have over the other.

Usually, traders are better off with more precise signals. This is not necessarily the case when information can be sold. Since more precise information increases the incentive to sell the information, traders 1 and 2 can be worse off with more precise information. This is the case when two information sellers sell information of the same quality. Using (13) (or (14)), letting $t_1 = t_2 = t$, substituting in for λ_2^s and $n_1 = n_2 = n^*$ using (12) and (17), and simplifying, each seller's total expected profit equals

$$\Pi_i(n^*, n^*, t, t) = \frac{1}{(2h\phi)^{1/2}} \frac{t^{1/2}(1 - t^2)^{1/4}}{1 + t + (1 - t^2)^{1/2}}. \tag{18}$$

The information sellers want to sell their information to at least one individual, i.e., $n^* \geq 1$, if and only if $t = \tau/(\tau + h) \geq (3/4)^{1/2}$. Over this range of values of t, $\Pi_i(n^*, n^*, t, t)$ is decreasing in t. Further, each seller's total expected profit tends to zero as their information becomes perfect, i.e., t approaches 1. This is because they sell their information to an increasing number of buyers. If both traders, 1 and 2, have perfect information, i.e., $\tau_1 = \tau_2 = \infty$, equivalently $t_1 = t_2 = 1$, then there is no Nash equilibrium; (15) becomes $n_1 = n_2 + 1$ and (16) becomes $n_2 = n_1 + 1$. Each trader wants to sell the information to one more person than the other.

Figure 1 illustrates the effect of a change in the quality of one trader's information on the traders' total expected profits. Holding trader 1's precision fixed with $t_1 = 0.99$, trader 1's total expected profit decreases as t_2 increases. Trader 2's total expected profit increases as t_2 increases from 0.758 to 0.947 but decreases beyond 0.947.

Proposition 3 has an interesting implication for the cross-sectional relation between the statistical quality and the price of information. Cross-sectionally, across securities (or across time for a given security), more informative signals can sell for a lower price. This is because, in equilibrium, more informative signals are sold to more individuals which reduces the profitability of trading on the signals. Suppose traders 1 and 2 sell information of the same quality, $t_1 = t_2 = t$. The price of the information equals an individual trader's expected trading profit, which is given by

$$\frac{\Pi_i(n^*, n^*, t, t)}{n^* + 1} = \frac{1}{(2h\phi)^{1/2}} \frac{t^{1/2}(1 - t^2)^{3/4}}{1 + t + (1 - t^2)^{1/2}}. \tag{19}$$

For values of t for which information sellers would sell their information to at least one individual, i.e., $t \geq (3/4)^{1/2}$ (19) is decreasing in t; the more informative the signals being sold, the lower the price. Now, suppose there are two traders selling information on security A with $t_1 = t_2 = t_A$, and two traders selling information on security B with $t_1 = t_2 = t_B$. Suppose $t_A > t_B$, but that other things are equal, $h_A = h_B$ and $\phi_A = \phi_B$. Finally, suppose that $t_B \geq (3/4)^{1/2}$, so for both securities $n^* \geq 1$. Even though the information on security A is statistically more informative, it sells for a lower price. So while individuals purchasing the information on either A or B pay a fair price, an analyst testing the forecasting power of the two signals would conclude that the cheaper signal is more informative.

Figure 2 uses the earlier example of Fig. 1 to illustrate how information prices vary as the precision of one trader's signal varies. Holding trader 1's precision fixed with $t_1 = 0.99$, the price of both sellers' information decreases as trader 2's precision increases (t_2 is plotted on the horizontal axis). Trader 1's price decreases for two reasons: his information is less profitable to trade on for a given number of traders and the two traders sell their information more widely. Trader 2's information becomes more

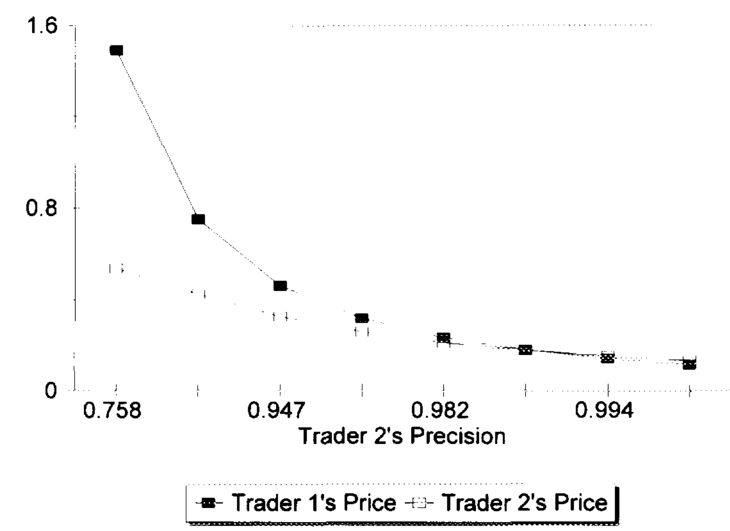

FIG. 2. Price of information.

profitable to trade on for a given number of traders, but the effect of selling the information more widely more than offsets this effect and lowers trader 2's price.

We assumed that the error components of the information sellers' signals were independent. Suppose instead that the error components were perfectly correlated, $\varepsilon_1 = \varepsilon_2$. It can be shown that, like the case in which the information sellers both had perfect information, there is no Nash equilibrium; each seller wants to sell the information to one more person than the other. The reason that the results are the same appears to derive from the way in which sellers' choices depend on the precisions of the two sellers' signals. Recall that the optimal choices of traders 1 and 2, (15) and (16), depend on the precision of their signals only through the correlation between $\theta + \varepsilon_1$ and $\theta + \varepsilon_2$. In both the case with perfect information and the case with perfectly correlated error components, $\mathrm{corr}(\theta + \varepsilon_1, \theta + \varepsilon_2) = 1$. We conjecture that the equilibrium in which the error components are imperfectly correlated also has the same general form.[6]

Our model has two informed traders who both sell their information. Suppose, though, that there were also traders who observe, but cannot sell, information (as in Section II). With this generalization, the equilibrium with information selling by two sellers can be compared to the equilibrium of a two-leader Stackelberg game without information selling. Unlike the case with one information seller, the results for the two models are not equivalent. Consider the perfect information case with $k > 2$ traders who observe θ. A two-leader Stackelberg game entails the following timing: first, the market maker announces a pricing rule, then two traders simultaneously commit to trading strategies, and then traders observe their information and submit their trades. In equilibrium, the two Stackelberg leaders trade $\theta/3\lambda_2^S$ shares and the $k - 2$ followers each trade $\theta/3(k - 1)\lambda_2^S$ shares, where λ_2^S is the slope of the pricing rule. There is, however, no equilibrium with information selling and two sellers. Analogous to our earlier results, seller i would want to sell his information to $n_j + k - 1$ new traders. The results for the two models are still not equivalent when traders observe imperfect and asymmetric information. Consider our two-information-seller model with imperfect information and $\tau_1 = \tau_2 = \tau$. Add to this model one additional trader who observes but cannot sell $\theta + \varepsilon_1$ and one additional trader who observes but cannot sell $\theta + \varepsilon_2$. It can be shown that, in equilibrium, each seller sells their information to at least one person. This equilibrium is not equivalent to that of a two-leader Stackelberg game (with the same timing as described above for

[6] We also solved a two-seller model in which the value of the asset is $\theta_1 + \theta_2$ and seller i observes θ_i. Here too, sellers' choices of how widely to sell their information depend on the statistical properties of θ_1 and θ_2 only through the correlation between the two signals.

the perfect-information case). It can be shown that for $\tau/(\tau + h) < 0.73$, aggregate equilibrium trading (on each signal) is more aggressive in the Stackelberg game and for $\tau/(\tau + h) > 0.73$, aggregate equilibrium trading (on each signal) is more aggressive in the information-selling game.

We conclude this Section by discussing the possibility that information sellers add noise to their signals before they sell them; such a setting is considered, for example, in Admati and Pfleiderer (1986). Since a seller's profit might decrease as the precision of his information exogenously increases, it is plausible that adding noise (or collecting less precise information than is available) is a profitable strategy. Consider an example in which sellers can add noise to the information that they sell and in which the sellers do not trade themselves. This eliminates the incentive for a seller to bias the noise.[7] Seller i observes $\theta_i + \varepsilon_i$, where $\tau_i/(\tau_i + h) = 2^{3/2}/3$ for $i = 1, 2$. Seller i can sell the signal as is, or can add noise and sell the signal $\theta_i + \varepsilon_i + \eta_i$ (the added noise is the same for all of seller i's clients), where η_i is normally distributed with mean zero and is independent of the other random variables. Letting ν denote the precision of $\varepsilon_i + \eta_i$, assume that $\nu/(\nu + h) = 3^{1/2}/2$. Thus, seller i's decision as to whether to add noise is a choice between $t_i = 2^{3/2}/3$ and $t_i = 3^{1/2}/2$. Consistent with the earlier analysis, the timing is as follows: first, the market maker announces a pricing rule, $\mu + \lambda^a\omega$, then traders 1 and 2 simultaneously choose t_1 and t_2 respectively, then traders 1 and 2, having observed the choices of t_1 and t_2 simultaneously choose n_1 and n_2 respectively, and then the $n_1 + n_2$ traders observe their information and submit their trades.

Once the sellers choose t_1 and t_2, how will they choose n_1 and n_2? In answering this question, we account for the fact that the number of people to whom sellers sell their signals must be an integer. If both sellers add noise to their signals, $t_i = 3^{1/2}/2$, then each will choose to sell their signal to 2 traders and if neither seller adds noise, $t_i = 2^{3/2}/3$, then each will choose to sell their signal to 3 traders. This is $n^* + 1$; see (17) (adding 1 to n^* replaces the seller who previously traded). In the former case each seller's expected profit is $0.077/\lambda^a$ and in the latter case each seller's expected profit is $0.061/\lambda^a$. This follows from (13), replacing $n_i + 1$ with n_i and λ_2^s with λ^a. Now suppose that only one seller adds noise. In this case, $n^* + 1$ is not an integer. Instead, it can be shown that it is a Nash equilibrium in this subgame for both sellers to sell their signal to 2 traders.

[7] This specification would not be important for the rest of the analysis in this Section (see Footnote 4), but it simplifies the analysis when adding noise to signals is a possibility. If the sellers traded for themselves and if they added noise before selling their signals, then a new trading equilibrium would have to be derived. The equilibrium would have to allow for one trader who observes $\theta + \varepsilon_1$, one trader who observes $\theta + \varepsilon_2$, and n_i traders who observe $\theta + \varepsilon_i + \eta_i$, where η_i is the (common) noise added to the signal of seller i.

In this case, the seller that adds noise has an expected profit of $0.065/\lambda^a$ and the seller who does not add noise has an expected profit of $0.092/\lambda^a$.[8]

Given how information sellers will choose n_i and the resulting expected profits, how will sellers choose t_i? Since $0.077/\lambda^a < 0.092/\lambda^a$, if one seller was certainly going to add noise then the other seller would not add noise. Since $0.061/\lambda^a < 0.065/\lambda^a$, if one seller was certainly not going to add noise then the other seller would add noise. Thus, there is no pure-strategy Nash equilibrium. It is straightforward to derive the symmetric mixed-strategy Nash equilibrium choices of t_1 and t_2. Each seller adds noise with probability 0.21 and does not add noise with probability 0.79. The incentive to add noise is due to the effect on sellers' decisions as to how widely to sell the information. If the timing is reversed, first n_i is chosen and then t_i is chosen, then neither seller would add noise. This is because holding n_1, n_2, and t_j fixed, seller i's expected profit is increasing in t_i.

IV. CONCLUDING REMARKS

Our paper develops an explanation for why firms with private information on securities have the incentive to sell their information. By endogenizing their incentive to sell information, this model could be useful for studying a number of more detailed issues associated with information selling. For instance, how can an information seller establish the credibility necessary to sell information (see Allen (1990))? What is the role of the information seller's reputation and how does he manage his reputation? Suppose a broker makes what turns out to be a bad investment recommendation. Might the broker reimburse, to some extent, the client's losses (see Boot *et al.* (1993))? How would information be priced if it were long lived and the seller could continue to sell the information over time? In effect, selling long-lived information entails a durable goods problem like that studied by Coase (1972). How would information be priced if a purchaser could easily resell the information?

It would also be interesting to consider the possibility that informed traders exchange information with each other. This is particularly important as it relates to insider trading, the incentive for corporate employees to share information within a firm, and the consequent efficiency of corpo-

[8] If one seller adds noise and the other does not, then it is also a Nash equilibrium in the subgame for both sellers to sell their signal to three traders. In this case, the seller that adds noise has an expected profit of $0.048/\lambda^a$ and the seller that does not add noise has an expected profit of $0.074/\lambda^a$. Both sellers' expected profits are lower in this equilibrium so it is presumed that the sellers coordinate on $n_1 = n_2 = 2$. The choice of $n_1 = n_2 = 2$ for this case has no qualitative effects on the analysis that follows.

rate decision making. A corporate benefit of information sharing is better business decisions. A personal cost, however, might be that personal trading profits are reduced by the information sharing. How, then, would internal compensation systems align incentives? See Haft (1982) for a discussion of insider trading and the sharing of corporate information.

In our analysis, information sellers choose how widely to sell their information before observing the realization of the signal to be sold. This is like a financial publication to which people subscribe. What happens if the information seller first observes the realization of the signal to be sold and then determines how widely to sell it? This is like a brokerage firm's decision of whether to pass information along to customers. If information were always sold at a fixed price, then a broker may choose not to sell extreme signal realizations (the ones that are highly profitable to trade on). Perhaps payment through trading commissions, in which the broker receives a larger payment for more extreme realizations, resolves this tension; see Brennan and Chordia (1993). Also, under what circumstances might a brokerage firm have the incentive to trade first for its own account and then sell the information to its customers?

Another interesting possibility involves information complementarities. Suppose some information is more valuable for individuals who possess information from other sources. For instance, the value of information on the earnings prospects of firms in a particular industry might be enhanced by information on the prospects of the economy as a whole. In a case like this, the price that one seller charges might be positively related to the precision of another seller's information. If sellers choose the precision of their information, then such complementarities might give rise to multiple equilibria; sellers might all choose low-precision information or sellers might all choose high-precision information.

In addition, with information complementarities a risk-neutral informed trader might sell his information even if there are no other traders who initially possess valuable trading information. Consider a simple example, chosen so that we can use results already derived in the paper. Trader 1 observes $\theta + \varepsilon_1$. Trader 2 observes $|\theta|$ and $|\varepsilon_1|$. If trader 1 doesn't sell his information to trader 2, then trader 2 has no valuable trading information. Trader 1 has an expected trading profit of $\Pi_1(0, 0, t_1, 0)$ and trader 2 has an expected trading profit of 0. If, however, trader 1 sells his information to trader 2, then (ignoring the zero-probability event $\theta + \varepsilon_1 = 0$) trader 2 has perfect information.[9] In this case, trader 1 has an expected trading profit

[9] Suppose $\theta + \varepsilon_1 \neq 0$. If $|\theta| + |\varepsilon_1| = \theta + \varepsilon_1$ or $|\theta| - |\varepsilon_1| = \theta + \varepsilon_1$ then trader 2 infers that $\theta = |\theta|$, and if $-|\theta| + |\varepsilon_1| = \theta + \varepsilon_1$ or $-|\theta| - |\varepsilon_1| = \theta + \varepsilon_1$ then trader 2 infers that $\theta = -|\theta|$. The zero-probability event $\theta + \varepsilon_1 = 0$ can be explicitly treated by introducing two more signals. Let $s_1 = s_2\theta + (1 - s_2)\varepsilon_1$, where $s_2 = 1$ with probability 1/2, $s_2 = 0$ with probability 1/2, and s_2 is independent of the other random variables. Assume that if $\theta + \varepsilon_1 = 0$, then trader 1 also

of $\Pi_1(0, 0, t_1, 1)$ and trader 2 has an expected trading profit of $\Pi_2(0, 0, t_1, 1)$. If trader 1 sells the information for a price equal to its expected value, $\Pi_2(0, 0, t_1, 1)$, then his total expected revenue from selling the information equals $\Pi_1(0, 0, t_1, 1) + \Pi_2(0, 0, t_1, 1)$. Selling the information to trader 2 makes the market more competitive, and this is disadvantageous for trader 1. Nevertheless, if t_1 is not too high, trader 1's total expected revenues are higher if he sells the information. Specifically, using (13) and (14) and taking λ_s^2 as given, $\Pi_1(0, 0, t_1, 1) + \Pi_2(0, 0, t_1, 1) > \Pi_1(0, 0, t_1, 0)$ if $t_1 < .877$.[10] Trader 1 can be better off selling his information because the information is more valuable if possessed by trader 2. This is not the case, though, when t_1 is close to 1. In such a case, trader 1 has very precise information already and the information complementarity is not worth much—it does not compensate trader 1 for the increase in trading competition.

The model developed in this paper can be applied to other strategic situations as well. For instance, similar models have been applied to patent licensing (see Kamien (1992)). Consider the simplest analogue to the model of Section II. There are k firms in an industry, one of which licenses the technology to n new firms. Then, facing an exogenous demand function, the $n + k$ firms choose outputs in Cournot fashion. The licensing leads to lower aggregate industry profits but higher profits for the licensor. A difference is that in the information-selling model, the market maker's pricing rule (the analogue to the industry demand function) is endogenous. Now consider the analogue to the model in Section III. With two licensors, there is no Nash equilibrium. Each licensor wants to sell the license to one more firm than the other licensor. This is like the information-selling outcome when the two sellers have perfect information. Note that the no-resale assumption fits better in the patent licensing setting. It would presumably be easier to detect an illegitimately transferred production technology as compared to illegitimately transferred securities information.

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observes s_1 and trader 2 also observes s_2. If trader 1 sells all of his information to trader 2, then trader 2 has perfect information even if $\theta + \varepsilon_1 = 0$. For $\theta + \varepsilon_1 = 0$, if $s_2 = 1$ trader 2 infers that $\theta = s_1$, and if $s_2 = 0$ trader 2 infers that $\theta = -s_1$. Further, when $\theta + \varepsilon_1 = 0$, trader 1 cannot profit from knowing $\theta + \varepsilon_1$ and s_1. This is the same as in the case in which trader 1 only observes $\theta + \varepsilon_1 = 0$.

[10] As in the previous analysis, the market maker would anticipate whether trader 1 would sell his information and he would choose λ_s^2 accordingly. If $t > 0.877$, so that trader 1 would not sell his information, then λ_s^2 would equal (12) evaluated with $\tau_2 = 0$ and $N_1 = 1/2$. This is the usual liquidity parameter when there is one imperfectly informed trader. If $t < 0.877$, so that trader 1 would sell his information, then λ_s^2 would equal (12) evaluated with $\tau_2 = \infty$ and $N_1 = N_2 = 1/2$. This is the usual liquidity parameter when there is one imperfectly informed trader and one perfectly informed trader.

APPENDIX

Proof of Lemma 2. Taking λ_2^s, β_1^s, and β_2^s as given, a trader who observes $\theta + \varepsilon_1$ solves the problem

$$\max_{x_1} E[x_1(\tilde{\theta} - \lambda_2^s(n_1\beta_1^s(\tilde{\theta} + \tilde{\varepsilon}_1) + (n_2 + 1)\beta_2^s(\tilde{\theta} + \tilde{\varepsilon}_2) + x_1 + \tilde{z})) \mid \tilde{\theta} + \tilde{\varepsilon}_1 = \theta + \varepsilon_1], \tag{20}$$

which can be rewritten as

$$\max_{x_1} x_1((\theta + \varepsilon_1)t_1 - \lambda_2^s(n_1\beta_1^s(\theta + \varepsilon_1) + (n_2 + 1)\beta_2^s(\theta + \varepsilon_1)t_1 + x_1)), \tag{21}$$

where $t_1 = \tau_1/(\tau_1 + h)$. The solution to this problem is

$$x_1 = \frac{t_1 - \lambda_2^s(n_1\beta_1^s + (n_2 + 1)\beta_2^s t_1)}{2\lambda_2^s}(\theta + \varepsilon_1). \tag{22}$$

Similarly, taking λ_2^s, β_1^s, and β_2^s as given, the optimal trade for a trader who observes $\theta + \varepsilon_2$ is

$$x_2 = \frac{t_2 - \lambda_2^s((n_1 + 1)\beta_1^s t_2 + n_2\beta_2^s)}{2\lambda_2^s}(\theta + \varepsilon_2), \tag{23}$$

where $t_2 = \tau_2/(\tau_2 + h)$. The Nash equilibrium among traders is found by solving the two equations

$$\beta_1^s = \frac{t_1 - \lambda_2^s(n_1\beta_1^s + (n_2 + 1)\beta_2^s t_1)}{2\lambda_2^s} \tag{24}$$

and

$$\beta_2^s = \frac{t_2 - \lambda_2^s((n_1 + 1)\beta_1^s t_2 + n_2\beta_2^s)}{2\lambda_2^s}. \tag{25}$$

This yields (10) and (11). The pricing rule $\mu + \lambda_2^s\omega = \mu + E[\tilde{\theta} \mid \tilde{\omega} = \omega]$ is satisfied for

$$\begin{aligned}\lambda_2^s &= \frac{\operatorname{cov}(\tilde{\theta}, \tilde{\omega})}{\operatorname{var}(\tilde{\omega})}\\ &= \frac{\operatorname{cov}(\tilde{\theta}, (n_1 + 1)\beta_1^s(\tilde{\theta} + \tilde{\varepsilon}_1) + (n_2 + 1)\beta_2^s(\tilde{\theta} + \tilde{\varepsilon}_2) + \tilde{z})}{\operatorname{var}((n_1 + 1)\beta_1^s(\tilde{\theta} + \tilde{\varepsilon}_1) + (n_2 + 1)\beta_2^s(\tilde{\theta} + \tilde{\varepsilon}_2) + \tilde{z})}.\end{aligned} \tag{26}$$

Substituting in for β_1^s and β_2^s using (10) and (11) and solving for λ_2^s yields (12). ■

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