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Information and the Cost of Capital

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ABSTRACT

We investigate the role of information in affecting a firm's cost of capital. We show that differences in the composition of information between public and private information affect the cost of capital, with investors demanding a higher return to hold stocks with greater private information. This higher return arises because informed investors are better able to shift their portfolio to incorporate new information, and uninformed investors are thus disadvantaged. In equilibrium, the quantity and quality of information affect asset prices. We show firms can influence their cost of capital by choosing features like accounting treatments, analyst coverage, and market microstructure.

FUNDAMENTAL TO A VARIETY OF CORPORATE DECISIONS is a firm's cost of capital. From determining the hurdle rate for investment projects to influencing the composition of the firm's capital structure, the cost of capital influences the operations of the firm and its subsequent profitability. Given this importance, it is not surprising that a wide range of policy prescriptions has been advanced to help companies lower this cost. For example, Arthur Levitt, the former chairman of the Securities and Exchange Commission, suggests that "high quality accounting standards . . . improve liquidity [and] reduce capital costs."[1] The Nasdaq stock market argues that its trading system "most effectively enhances the attractiveness of a company's stock to investors."[2] And investment banks routinely solicit underwriting business by arguing that their financial analysts will lower a company's cost of capital by attracting a greater institutional following to the stock. While accounting standards, market microstructure, and financial analysts each clearly differ, these factors can all be thought of as influencing the information structure surrounding a company's stock.[3]

Paradoxically, asset-pricing models include none of these factors in determining the required return for a company's stock. While more recent asset-pricing

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[1] Remarks by Arthur Levitt, Inter-American Development Bank, September 29, 1997. Also cited in Admati and Pfleiderer (2000).

[2] See the Nasdaq website, www.nasdaq.com. See also Masulis and Shivakumar (2002).

[3] Indeed, Arthur Levitt argues even further: "Quality information is the lifeblood of strong, vibrant markets. Without it, liquidity dries up. Fair and efficient markets cease to exist." See remarks at Economic Club of Washington, April 6, 2000.

models (see Fama and French (1992, 1993)) admit the possibility that something other than market risk may affect required returns, these alternative factors do not include the role of information. This exclusion is particularly puzzling given the presumed importance of market efficiency in asset pricing. If information matters for the market, why then should it not also matter for the firms that are in it?

In this research, we investigate the role of information in affecting a firm's cost of capital. Our particular focus is on the specific roles played by public and private information. The argument we develop here is that differences in the composition of information between public and private information affect the cost of capital, with investors demanding a higher return to hold stocks with greater private (and correspondingly less public) information. This higher return reflects the fact that private information increases the risk to uninformed investors of holding the stock because informed investors are better able to shift their portfolio weights to incorporate new information. This cross-sectional effect results in the uninformed traders always holding too much of stocks with bad news, and too little of stocks with good news. Holding more stocks cannot remove this risk because the uninformed are always on the wrong side; holding no stocks is suboptimal because uninformed utility is higher when holding some risky assets. Moreover, the standard separation theorem that typically characterizes asset-pricing models does not hold here because informed and uninformed investors perceive different risks and returns, and thus hold different portfolios.[4] Private information thus induces a new form of systematic risk, and in equilibrium investors require compensation for this risk.

We develop our results in a multiasset rational expectations equilibrium model that includes public and private information, and informed and uninformed investors. Important features of the model are risk-averse investors, a positive net supply (on average) of each risky asset, and incomplete markets. We find a partially revealing rational expectations equilibrium in which assets generally command a risk premium. The model demonstrates how in equilibrium the quantity and quality of information affect asset prices, resulting in cross-sectional differences in firms' required returns. What is particularly intriguing about the model is that it demonstrates a role for both public and private information to affect a firm's required return. This provides a rationale for how an individual firm can influence its cost of capital by choosing features like its accounting treatments, financial analyst coverage, and market microstructure. We also show why firms with little available information, such as IPOs, face high costs of capital: In general, more information, even if it is privately held, is better than no information at all.

Prior researchers have investigated how private information affects asset prices in a variety of contexts. Three streams of the literature are most relevant for our work here. First, building from the classic analysis by Grossman

[4] The informed traders hold different weights of each asset in their portfolios depending on the information they learn. The uninformed do not know the information, so they are unable to replicate these optimal weights, and end up holding a different portfolio from that of the informed traders.

and Stiglitz (1980), a number of authors have looked at the role of private information in rational expectations models. Admati (1985) analyzed the effects of asymmetric information in a multiasset model. Her analysis focused on how an asset's equilibrium price is affected by information on its own fundamentals and those of other assets. Because agents in her model have diverse information, she finds that each agent has a different risk-return tradeoff; this result is very similar to our finding here that informed and uninformed investors hold different portfolios. While Admati provides an elegant analysis of multiasset equilibrium, her focus is not on the public-versus-private information issues we consider. Wang (1993) showed in a two-asset multiperiod model that asymmetric information has two effects on asset prices. First, uninformed investors require a risk premium to compensate them for the adverse selection problem that arises from trading with informed traders. Second, informed trading also makes prices more informative, thereby reducing the risk for the uninformed and lowering the risk premium. The overall effect on the equilibrium required return in this model is ambiguous. Because the model allows only one risky asset, it is not clear how, if at all, information affects cross-sectional returns, or how information affects portfolio selection.[5] One way to interpret our results is that holding the amount of information constant, the adverse selection effect prevails, so that in our multiasset equilibrium, cross-sectional effects arise.

Dow and Gorton (1995) provide an alternative analysis in which informed traders profit from their information, and consequently uninformed traders lose relative to the informed. For profitable informed trade to be possible, it must not be possible for the uninformed to replicate the portfolio(s) of the informed. We do this with the standard device of noise trade so that we can focus on the effect of private-versus-public information on the cost of capital. Dow and Gorton instead restrict the uninformeds' portfolios so that they cannot buy the market. They do not consider public-versus-private information or the cost of capital, but their approach could also be used to address these issues.

A second stream of related research considers the role of information when it is incomplete but not asymmetric.[6] Of particular relevance here is Merton (1987), who investigates the capital market equilibrium when agents are unaware of the existence of certain assets. In Merton's model, all agents who know of an asset agree on its return distribution, but information is incomplete, in the sense that not all agents know about every asset. Merton shows that in equilibrium the value of a firm is always lower when there is incomplete information and a smaller investor base. In our model, all investors know about every asset, but information is asymmetric: Some investors know more than others about returns. While both approaches lead to cross-sectional differences in the cost

[5] Another important difference between our work and that of Wang (1993) or Admati (1985) is that these authors do not consider the role of public information. As we show here, increasing the quantity of public information about an asset can affect the asset's equilibrium required return.

[6] Yet another stream of research in this area considers the effects of uncertainty about and estimation of return distribution parameters. This estimation risk raises the required return for investors, (see Barry and Brown (1984); and Coles, Lowenstein, and Suay (1995)). See also Basak and Cuoco (1998) and Shapiro (2002) for more development of the investor recognition hypothesis.

of capital, there is an important difference with respect to their robustness to arbitrage.

Finally, a third stream of related research considers the role of information disclosure by firms. Disclosure essentially turns private information into public information, so this literature addresses the role of public information in affecting asset prices. Diamond (1985) developed an equilibrium model in which public information makes all traders better off. What drives this result is that information production is costly, and so disclosure by the firm obviates the need for each individual to expend resources on information gathering.[7] While our model also shows a positive role for public information, our result arises because public information reduces the risk to uninformed traders of holding the asset. Diamond and Verrecchia (1991) consider a different risk issue by analyzing how disclosure affects the willingness of market makers to provide liquidity for a stock. Using a Kyle (1985) type model, they show that disclosure changes the risks for market makers, which in turn induces entry or exit by dealers. In this model, disclosure can improve or worsen liquidity depending upon these dealer decisions. Our analysis does not consider dealers, but the models are related, in that public information influences the riskiness of holding the stock. Research by Fishman and Haggerty (1997) and Admati and Pfleiderer (2000) considers other important aspects of disclosure, such as the role of insiders and strategic issues in disclosure, but these issues are outside the scope of the problem considered here.[8]

What emerges from our research is a demonstration of why a firm's information structure affects its equilibrium return. This dictates that a firm's cost of capital is also influenced by information, providing a linkage between asset pricing, corporate finance, and the information structure of corporate securities. A particular empirical prediction of our model is that in comparing two stocks that are otherwise identical, the stock with more private information and less public information will have a larger expected excess return. In a companion empirical paper (Easley, Hvidjkaer, and O'Hara (2002)), we test this prediction using a structural microstructure model to provide estimates of information-based trading for a large cross section of stocks. Our findings there provide strong evidence of the effects we derive here. Our model also develops a number of other empirical implications, as yet untested, on the effects of the dispersion of information, of the quantity of information, and of the quality of public and private information on a firm's cost of capital. We illustrate

[7] Diamond (1985, p. 1073) notes that in his model, "an even better arrangement would be an agreement among traders to all refrain from acquiring any new information, or a tax on information acquisition." In our model, more information is always better than less information, so that this effect does not arise.

[8] Fishman and Haggerty (1997) investigate how disclosure affects the utility of corporate insiders and outsiders. They find that mandatory disclosure can make insiders better off, even when insiders do not actually know any value-relevant information. Admati and Pfleiderer (2000) provide a very interesting analysis of the externality that disclosure imposes on firms. Because one firm's disclosure may be informative for other firms, it is cheaper for a firm to let others do costly disclosure. Without required disclosure, therefore, there may be an underprovision of public information.

the potential magnitude of some of these effects through simple numerical examples.

This paper is organized as follows. Section I develops a rational expectations model including many assets, many sources of uncertainty, and informed and uninformed traders. We characterize the demands of the informed and uninformed traders, and we demonstrate that a nonrevealing rational expectations equilibrium exists. In Section II, we then analyze the equilibrium and determine how the equilibrium return differs across stocks. In this section, we derive our results on the specific influence of private and public information on asset returns. Section III then considers the impact of various aspects of a firm's information structure on its cost of capital. Section IV discusses some extensions and generalizations of our model. Section VI concludes.

I. Information and Asset Prices in Equilibrium

In this section, we develop a rational expectations equilibrium model in which both public and private information can affect asset values. We first describe the information surrounding a company's securities, and how this information is disseminated to traders. We then derive demands for each asset by informed traders who know the private information and by uninformed traders who do not. Because informed traders' information affects their demands, it is reflected in equilibrium prices. In a rational expectations equilibrium, uninformed traders make correct inferences about this private information from prices. We solve for rational expectations equilibrium prices and derive the equilibrium required return for each asset. This required return is the company's cost of capital.

A. The Basic Structure

We consider a two-period model: today when investors choose portfolios, and tomorrow when the assets in these portfolios pay off. There is one risk-free asset, money, which has a constant price of 1. There are K risky stocks indexed by $k = 1, \ldots, K$. Future values, v_k, are independently, normally distributed with mean $\bar{v}_k$ and precision ρ_k. The per-capita supply of stock k, x_k, is also independently, normally distributed with mean $\bar{x}_k$ and precision η_k.[9] Stock prices, p_k, are determined in the market. Traders trade today at prices $(1, p_1, \ldots, p_k)$ per share and receive payoffs tomorrow of $(1, \tilde{v}_1, \ldots, \tilde{v}_k)$ per share.

Investors receive signals today about the future values of these stocks. For stock k, there are I_k signals, where I_k is an integer. These signals, s_{k1}, $s_{k2}, \ldots, s_{kI_k}$, are drawn independently from a normal distribution with mean v_k,

[9] This assumes a random net supply, which is a standard modeling device in rational expectations models. One theoretical interpretation is that this approximates noise trading in the market. A more practical example of this concept is portfolio managers' current switch toward using float-based indices from shares-outstanding indices. This shift is occurring because for many stocks, the actual number of shares that trade in the market is a more meaningful number than the number of shares that exist. Determining this "float" essentially means finding the distribution of shares that trade in a given stock (a random variable), rather than taking the supply as given.

the future value of stock k, and precision γ_k. Some of these signals are public and some are private. The fraction of the signals about the value of stock k that is private is denoted α_k; the fraction of the signals that is public is $1 - \alpha_k$. All investors receive public signals before trade begins. Private signals are received only by informed traders. We let μ_k be the fraction of traders who receive the private signals about stock k. All of these random variables are independent and the investors know their distributions.[10]

Since the distributions are normal, and the signals are conditionally independent, the mean of any collection of signals is a sufficient statistic for the collection. Let

$$N_k = \sum_{i=1}^{\alpha_k I_k} s_{ki} \Big/ \alpha_k I_k, \quad M_k = \sum_{i=\alpha_k I_k+1}^{I_k} s_{ki} \Big/ (1-\alpha_k) I_k \tag{1}$$

be these sufficient statistics. Note that N_k is normally distributed with mean v_k and precision $\alpha_k I_k \gamma_k$ and M_k is normal with mean v_k and precision $(1-\alpha_k) I_k \gamma_k$. So by varying α_k, we keep the total information content of signals constant while varying the amount of private-versus-public information.

There are J investors indexed by $j = 1, \ldots, J$. These investors all have CARA utility with coefficient of risk aversion $\delta > 0$. These investors must in equilibrium hold the available supply of money and stocks. Because the investors are risk averse, and the stocks are risky, the risk will be priced in equilibrium. The question that we are interested in is how the distribution of information affects asset prices and thus expected returns.

B. Investors' Decision Problems

Each investor chooses his demands for assets $k = 1, \ldots, K$ to maximize his expected utility subject to his budget constraint. The budget constraint today for the typical investor j is

$$m^j + \sum_k p_k z_k^j = \overline{m^j}, \tag{2}$$

where z_k^j is the number of shares of stock k he purchases, m^j is the amount of money he holds, and $\overline{m^j}$ is his initial wealth. His wealth tomorrow is the random variable

$$\tilde{w}^j = \sum_k v_k z_k^j + m^j. \tag{3}$$

Substituting from the budget constraint for $\overline{m^j}$, investor j's wealth can be written as the sum of capital gains and initial wealth,

$$\tilde{w}^j = \sum_k (v_k - p_k) z_k^j + \bar{m}^j. \tag{4}$$

[10] More precisely, the signals s_{ki} are independent conditional on v_k.

Suppose that conditional on all of investor *j*'s information, he conjectures that the payoffs on stocks are independent and that the distribution of v_k is normal with mean $\bar{v}_k^j$ and precision ρ_k^j. Then, because he has CARA utility and all distributions are normal, investor *j*'s objective function has a standard mean-variance expression. He thus chooses a portfolio to solve

$$\underset{\left(z_k^j\right)_{k=1}^{K}}{Max}\ E[\tilde{w}^j] - (\delta/2)Var^j[\tilde{w}^j]. \tag{5}$$

So investor *j*'s demand function for asset *k* is

$$z_k^j = \frac{\overline{v_k^j} - p_k}{\delta\left(\rho_k^j\right)^{-1}}. \tag{6}$$

The demand function for asset *k* in (6) depends upon investor *j*'s beliefs about the asset's risk and return. These beliefs differ depending upon whether or not the agent is informed. We first consider these beliefs for informed investors. It follows from Bayes' Rule that if *j* is informed about asset *k*, then his predicted distribution for v_k is normal with conditional mean and precision given by

$$\overline{v_k^j} = \frac{\rho_k \overline{v_k} + \gamma_k \sum_{i=1}^{I_K} s_{ki}}{\rho_k + \gamma_k I_K}, \quad \rho_K^j = \rho_K + \gamma_K I_K. \tag{7}$$

Thus, from (6) the demand for asset *k* by informed investor *j* is

$$z_k^{j*} = \frac{\rho_k \overline{v_k} + \gamma_k \sum_{i=1}^{I_k} s_{ki} - p_k(\rho_k + \gamma_k I_k)}{\delta} \equiv DI_k^*\left(\sum_{i=1}^{I_k} s_{ki}, p_k\right). \tag{8}$$

Solving for uninformed investors' demands is more complicated. These investors know the public signals, but not the private signals. What they do know, however, is that the demands of the informed traders affect the equilibrium price, and so they rationally make inferences about the underlying information from the price. To learn from the price, these investors must conjecture a form for the price function, and in equilibrium this conjecture must be correct. Suppose the uninformed conjecture the following price function

$$p_k = a\overline{v_k} + b\sum_{i=1}^{\alpha I_k} s_{ki} + c\sum_{i=\alpha_k I_{k+1}}^{I_k} s_{ki} - dx_k + e\bar{x}_k, \tag{9}$$

where *a, b, c, d*, and *e* are coefficients to be determined.

To compute the distribution of v_k, conditional on p_k, it is convenient to define the random variable θ_k to be

$$\theta_k = \frac{p_k - a\overline{v_k} - c\displaystyle\sum_{i=\alpha_k I_{k+1}}^{I_k} s_{ki} + \bar{x}_k(d-e)}{b\alpha_k I_k} = \frac{\displaystyle\sum_{i=1}^{\alpha_k I_k} s_{ki}}{\alpha_k I_k} - \left(\frac{d}{b\alpha_k I_k}\right)(x_k - \bar{x}_k). \quad (10)$$

What is important for our purposes is that the uninformed investors can compute θ_k, and that θ_k has mean v_k. Calculation shows that θ_k is normally distributed with mean v_k and precision $\rho_{\theta k}$ where

$$\rho_{\theta k} = \left[\left(\frac{d}{b\alpha_k I_k}\right)^2 \eta_k^{-1} + \left(\frac{1}{\alpha_k I_k}\right)\gamma_k^{-1}\right]^{-1}. \quad (11)$$

Using this information, we can compute the conditional mean and variance from the perspective of the uninformed trader. These are

$$\overline{v_k^j} = \frac{\rho_k\overline{v_k} + \gamma_k\displaystyle\sum_{i=\alpha_k I_k+1}^{I_k} s_{ki} + \rho_{\theta k}\theta_k}{\rho_k + \gamma_k(1-\alpha_k)I_k + \rho_{\theta k}}, \quad \rho_k^j = \rho_k + \gamma_k(1-\alpha_k)I_k + \rho_{\theta k}. \quad (12)$$

Each uninformed trader's demand for asset k is thus

$$\begin{aligned} z_k^{j*} &= \frac{\rho_k\overline{v_k} + \gamma_k\displaystyle\sum_{i=\alpha_k I_k+1}^{I_k} s_{ki} + \rho_{\theta k}\theta_k - p_k(\rho_k + \gamma_k(1-\alpha_k)I_k + \rho_{\theta k})}{\delta} \\ &\equiv DU_k^*\left(\sum_{i=\alpha_k I_k+1}^{I_k} s_{ki}, \theta_k, p_k\right). \end{aligned} \quad (13)$$

In the next section, we show that there is a rational expectations equilibrium in which the conjectures used to compute these demands are correct.

C. Equilibrium

In equilibrium, for each asset k, per-capita supply must equal per-capita demand, or

$$\mu_k DI_k^*\left(\sum_{i=1}^{I_k} s_{ki}, p_k\right) + (1-\mu_k)DU_k^*\left(\sum_{i=\alpha_k I_k+1}^{I_k} s_{ki}, \theta_k, p_k\right) = x_k. \quad (14)$$

We find the equilibrium by solving equation (14) for p_k and then verifying that p_k is of the form conjectured in (9). Proposition 1 characterizes this equilibrium.

PROPOSITION 1: *There exists a partially revealing rational expectations equilibrium in which, for each asset k,*

$$p_k = a\overline{v_k} + b\sum_{i=1}^{\alpha_k I_k} s_{ki} + c\sum_{i=\alpha_k I_k+1}^{I_k} s_{ki} - dx_k + e\bar{x}_k, \tag{15}$$

where

$$a = \rho_k/C_k, \quad b = \frac{\mu_k\gamma_k + \dfrac{(1-\mu_k)\rho_{\theta k}}{\alpha_k I_k}}{C_k}, \quad c = \gamma_k/C_k,$$

$$d = \frac{\delta + \dfrac{(1-\mu_k)\rho_{\theta k}\delta}{\alpha_k I_k\mu_k\gamma_k}}{C_k} \quad \textit{and} \quad e = \frac{\dfrac{(1-\mu_k)\rho_{\theta k}\delta}{\alpha_k I_k\mu_k\gamma_k}}{C_k},$$

where $C_k = \rho_k + (1-\alpha_k)I_k\gamma_k + \mu_k\alpha_k I_k\gamma_k + (1-\mu_k)\rho_{\theta k}$, *and* $\rho_{\theta k} = [(\mu_k\gamma_k\alpha_k I_k)^{-2}\eta_k^{-1}\delta^2 + (\alpha_k I_k\gamma_k)^{-1}]^{-1}$.

Proof: See the Appendix.

The proposition demonstrates that there exists a rational expectations equilibrium in which prices are partially revealing. So in equilibrium, informed and uninformed investors will have differing expectations.

II. Information and Cross-Sectional Asset Returns

Having established the equilibrium, in this section we turn to an analysis of how the equilibrium return differs across stocks. We show that this return depends on the information structure, with the levels of public and private information influencing the cross-sectional equilibrium return demanded by investors. The random return per share to holding asset k is $v_k - p_k$. The expected return per share to holding asset k for an investor with information set I, price and public information for an uninformed investor or all information for an informed investor, is thus $E[v_k \mid I] - p_k$. The average return per share over time for this investor is $E[E[v_k \mid I] - p_k] = E[v_k - p_k]$, where the expectation is computed with respect to prior information. This is common to all investors and is the return that an outside observer could compute per share for asset k.[11] The following proposition describes this equilibrium risk premium on asset k.

PROPOSITION 2: *The expected return per share for stock k is given by*

$$E[v_k - p_k] = \frac{\delta\bar{x}_k}{\rho_k + (1-\alpha_k)I_k\gamma_k + \mu_k\alpha_k I_k\gamma_k + (1-\mu_k)\rho_{\theta k}}.$$

[11] This average expected return per share is common across investors. Informed and uninformed investors do earn differing returns, but they do so by purchasing differing amounts of the asset based on their differing information.

Proof: See the Appendix.

Proposition 2 reveals a number of important properties of equilibrium asset returns. Inspecting the numerator reveals that the risk premium of a stock depends on agents' risk preferences (δ) and on the per-capita supply $\bar{x}_k$ of the stock. Obviously, if agents are risk neutral ($\delta = 0$), then the asset's underlying risk is not important to them, negating the need for any risk premium. If agents are risk averse, then there is a positive risk premium for asset k as long as the per-capita supply of the asset is on average positive.[12] It is important to note that $\bar{x}_k$ is the per-capita number of shares of asset k and not the portfolio weight, or fraction of wealth invested in asset k. In an economy with a large number of assets, the portfolio weights for all assets are small, but this has no effect on the expected return given in Proposition 2. Of course, if $\bar{x}_k = 0$ for all stocks then there is no risk premium for any stock. In such a world there is on an average no per-capita supply of any asset that needs to be held, so no agent has to bear any risk, and risk bearing is thus not rewarded. Even market risk would not be priced in this uninteresting economy. We focus instead on economies with assets that are in positive per-capita supply and which thus have positive expected return.

The risk premium is also affected by the stock's information structure. The denominator shows the influence of traders' prior beliefs and the effects of public and private information. If information on the asset is perfect (perfect prior information, $\rho_k = \infty$, or perfect signals, $\gamma_v = \infty$), then asset k is risk free and its price is its expected future value. When information is not perfect, the risk premium is positive. The greater the uncertainty about the asset's value, the smaller the precision, and the greater the stock's risk premium. In the following analysis, we examine the economically interesting case in which $\delta > 0$, $\overline{x_k} > 0$, $\rho_k < \infty$, $\gamma_k < \infty$, and there is a positive expected return on stock k.

We are interested in cross-sectional variation in this return. Most important is how the required return is affected by the amount of private information versus public information; that is, α_k. Proposition 3 details this effect.[13]

PROPOSITION 3: *For any stock k, and provided* $\mu_k < 1$, *shifting information from public to private increases the equilibrium required return, or*

$$\frac{\partial E\left[\tilde{v} - p_k\right]}{\partial \alpha_k} > 0$$

Proof: See the Appendix.

The proposition shows that if private signals are truly private to some traders, ($\mu_k < 1$), then the required return is increasing in α_k, the fraction of the signals

[12] This result also illustrates a feature that our approach and Merton's (1987) approach have in common. In his world, increasing the investor base allows risk to be shared more widely and so raises the value of the firm. Here reducing the per-capita supply has a similar effect.

[13] We treat α_k and I_k as continuous variables, ignoring integer constraints on $\alpha_k I_k$ and $(1 - \alpha_k)I_k$. Equivalent results could be obtained by changing $\alpha_k I_k$ and $(1 - \alpha_k)I_k$ in integer units.

about stock k that are private (when $\mu_k = 1$, all available information is actually public). This result has an important implication for cross-sectional returns: In comparing two stocks that are otherwise identical, the stock with more private and less public information will have a larger expected excess return. This occurs because when information is private, rather than public, uninformed investors cannot perfectly infer the information from prices, and consequently they view the stock as being riskier.

Cross-sectional returns on stocks will thus depend on the structure of information in each individual stock. To the extent that information structures are correlated with other more easily observable variables, these variables may proxy for the effects of information structure in explaining the cross section of returns. For example, if small firms have relatively more private and less public information than large firms, then uninformed investors will view them as being more risky and they will have higher expected excess returns.

A. A Numerical Example

The potential magnitude of this effect can be illustrated by a simple numerical example. The specific value to attach to some of the model's parameters is surely debatable. As our focus is on the comparative effects of changes induced by a stock's information structure, we adopt simple base levels for the model's structural parameters. Thus, we set the precisions of the random variables as η_k, γ_k, and $\rho_k = 1$, the mean per-capita supply as $\bar{x}_k = 1$, the risk-aversion coefficient as $\delta = 1$, the number of signals as $I_k = 10$, and the fraction of informed traders as $\mu_k = 0.2$. The risk premium for stock k is then found by substituting these parameter values, and the fraction of signals that are public (α_k) into the equation in Proposition 2. We then compute percentage changes in the risk premium caused by changes in the fraction of signals that are public, α_k.[14]

Table I, Panel A shows how changes in α_k affect the company's required excess return.[15] The example shows that changing α_k by 0.1 changes the expected risk premium by approximately 7.9%. Note that this is the percentage change in the risk premium, not the absolute change. Thus, moving information from private to public can have real effects on the equilibrium risk premium.

III. Mean-Variance Efficiency and the Risk Premium

The model above shows that in equilibrium, asset returns include a risk premium that depends upon the information structure of each stock. Thus, unlike in the standard CAPM pricing world, investors demand compensation

[14] These changes do not depend on the level of per-capita supply. We have set it in this example only because we will need the per-capita supply parameter for other examples, and we want the examples to be consistent.

[15] Note that the example focuses on changes in a stock's risk premium. A firm's cost of equity capital will generally be the risk premium added on to some riskless rate, which is not specified in our model. This riskless rate is exogenous to the firm and so our analysis focuses on the firm-specific risk premium.

Table I

Numerical Example: The Effect of Parameters on Excess Return

This table illustrates the percentage change in expected excess return ($\%\Delta ER_k$) for stock k generated by changes in the fraction of signals that are private (α_k), the fraction of traders who are informed (μ_k), and the precision of signals (γ_k). In each panel, the parameters other than the parameter of interest are fixed at $\rho_k = \gamma_k = \eta_k = 1, \delta = 1, \bar{x}_k = 1, I_k = 10, \mu_k = 0.2$ and $\alpha_k = 0.5$.

Panel A											
α_k	0		0.2		0.4		0.6		0.8		1.0
$\%\Delta ER_k$		15.6		15.5		15.6		15.9		16.4	
Panel B											
μ_k	0		0.2		0.4		0.6		0.8		1.0
$\%\Delta ER_k$		−27.8		−21.7		−10.2		−4.6		−2.2	
Panel C											
γ_k			0.8		0.9		1.0		1.1		1.2
$\%\Delta ER_k$				−11.3		−10.3		−9.5		−8.8	

for what can be viewed as factors idiosyncratic to each asset. Yet, it is also true that investors in our model have utility functions defined over means and variances, and so they, too, seek mean-variance efficiency in their asset choices. What then leads to the different equilibrium outcomes? In this section, we address this question by first discussing why this result is robust, and then turning to a more technical derivation of the mean-variance efficiency of our asymmetric information asset-pricing model.

A. Investor Behavior and the Risk Premium

Let us first consider why this result is not eviscerated by the usual arguments advanced in asset-pricing models. For example, one might conjecture that this effect would be removed by the uninformed investors optimally diversifying, or by simply not holding stocks with a large amount of private information. But this is not the case. Uninformed investors choose not to avoid this risk in equilibrium. They are rational, so they hold optimally diversified portfolios, but no matter how they diversify, they lose relative to the informed traders. To completely avoid this risk, the uninformed traders would have to hold only money, but this is not optimal; their utility is higher by holding the risky stocks. Although the model has only one trading period, it is easy to see that uninformed investors also would not choose to avoid this risk by buying and holding a fixed portfolio over time. In each trading period in an intertemporal model, uninformed investors reevaluate their portfolios. As prices change, they optimally change their holdings.

Could the uninformed arbitrage this effect away (or conversely, make arbitrage profits) by simply holding all high α stocks and shorting all low α stocks? Again, the answer is no. It is true that everyone, including the uninformed, know the αs. But the uninformed do not know the actual private information. Holding all high α stocks is extremely risky for the uninformed because these stocks have both good and bad news. The informed are able to buy more of the good-news stocks, and hold less of (or even short) the bad-news stocks, thereby allowing them to exploit their information; this option is not available to the uninformed.

This property of our equilibrium highlights an important difference between our asymmetric information model and Merton's (1987) incomplete information model. In Merton's model, arbitrage is possible, "if such stocks can be easily identified and if accurate estimation of the alphas [the excess returns] can be acquired at low cost . . . then professional money managers could improve performance by following a mechanical investment strategy tilted towards these stocks. If a sufficient quantity of such investments were undertaken then this extra excess return would disappear" (p. 507). In our model, everyone knows about the stocks, but they do not know what position to take. The informed hold different weights of the assets in their portfolio than do the uninformed. The uninformed cannot mimic the informed portfolio by holding all good information stocks because they do not know the information value, and holding equal weights of all of the stocks does not remove this risk.

The intuition for this result is similar to that of Rock's IPO (1986) underpricing explanation. In that analysis, the uninformed bid for new issues and so do informed insiders. When the information is good, the insiders buy larger amounts, and the uninformed correspondingly get less. When the information is bad, the insiders do not buy the new issue, and the uninformed end up holding most of it. Because the uninformed know this will happen, in equilibrium they demand a higher expected return to compensate. Here, the problem extends across all the assets, in that private information will again influence the portfolio outcomes of the informed and uninformed. Our result is that equilibrium asset returns will reflect this risk.

B. Mean-Variance Efficiency

The differing information that traders have results in differing perceptions of the efficient mean-standard deviation (of wealth) frontier. This causes informed and uninformed traders to select different portfolios, even though each investor is maximizing the same utility function defined over means and variances. To illustrate how this affects the equilibrium, we first look heuristically at the portfolio choice problem for any trader j, represented graphically by Figure 1.[16]

The perceived efficient frontier is linear, with a slope determined by the trader's perception of mean returns ($\bar{v}_k^j$) and standard deviations ($(\rho_k^j)^{-1/2}$) for assets. For an economy with one risky asset (and one riskless asset), the slope of this frontier according to trader j is $(\bar{v}_1^j - p_1)(\rho_1^j)^{1/2}$. The trader's indifference curves in expected wealth ($\bar{w}$)–standard deviation of wealth (σ_w) space have slope $\delta\sigma_w$.

[16] The same analysis holds for multiple assets, as long as markets are incomplete.

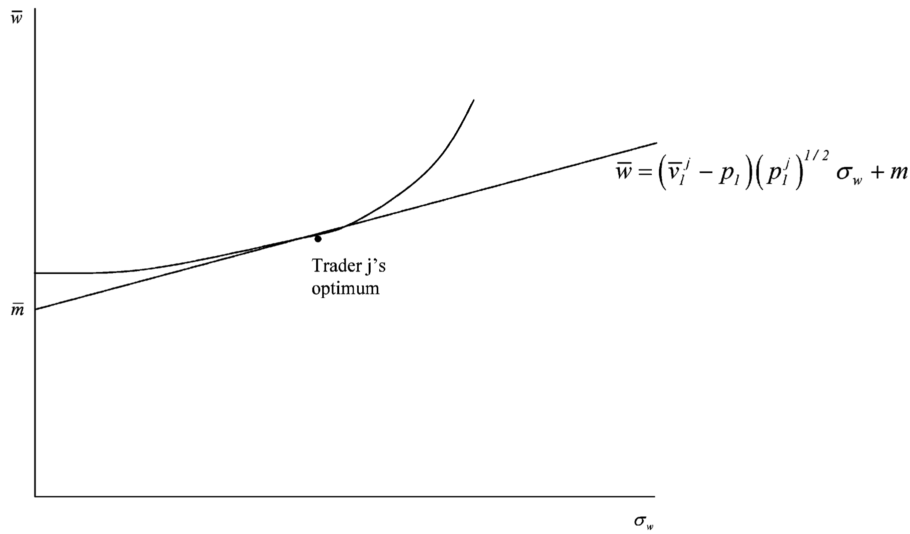

Figure 1. The efficient frontier for trader *j*. This figure shows the risk-return tradeoff confronting an investor *j*. The perceived efficient frontier is linear, with a slope determined by the trader's perception of mean returns and standard deviations for assets. For an economy with one risky asset (and one riskless asset) the slope of this frontier according to trader *j* is $(\bar{v}_1^j - p_1)(\rho_1^j)^{1/2}$.

If there is any private information about the risky asset, then in equilibrium informed traders have a larger precision; $\rho_1^I > \rho_1^U$ for informed trader I and uninformed trader U, respectively. The expected value of the asset depends on the information that informed traders receive and that uninformed traders partially infer from price. On an average, these expected values are both equal to the prior expected value of the asset, $E[\bar{v}^1] = E[\bar{v}^U] = \bar{v}$. Figure 2 shows the average portfolio choices of informed and uninformed traders denoted by X^I and X^U.

On an average, informed traders take on more risk by holding more of the risky asset. Informed traders' beliefs about mean returns are more responsive to signals than are uninformed traders' beliefs. So when there is good news, the informed hold even more of the risky asset, and when there is bad news, their holdings are reduced more than are the uninformed traders' holdings. If the news is bad enough, the informed hold less of the risky asset than do the uninformed. This effect is captured in Figure 3, where I_G and I_B (U_G and U_B) are the efficient frontiers for informed (uninformed) traders given good news and bad news, respectively.

C. Mean-Variance Efficiency and the Market Portfolio

An important feature of the portfolios above is that each trader's portfolio is mean-variance efficient conditional on his information, but the portfolios differ between informed and uninformed traders. In symmetric information models

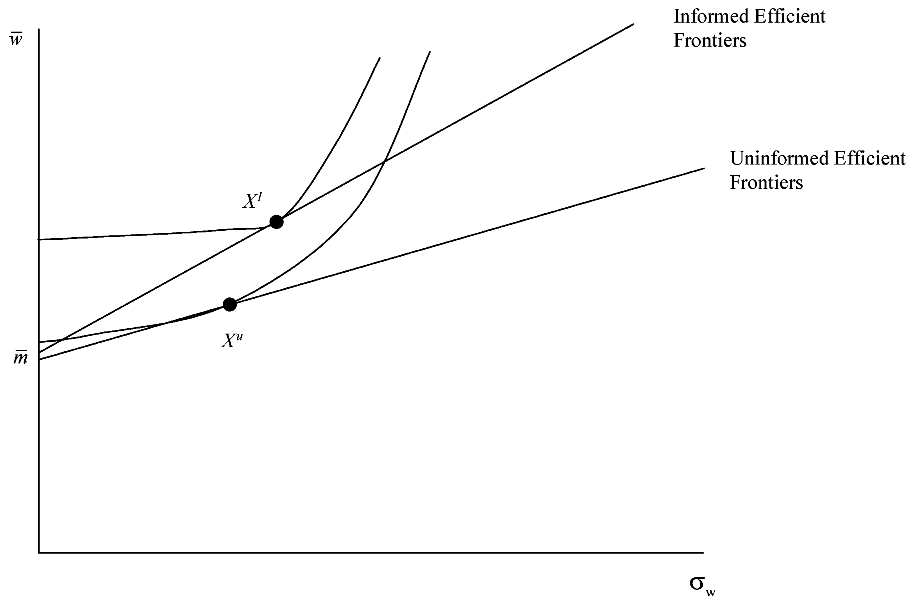

Figure 2. Efficient frontiers for informed and uninformed traders. This graph shows that the average efficient frontier is different for informed and uninformed traders. The frontier for the informed trader is above that of the uninformed trader because the informed trader knows more about the asset, and so faces a lower risk-return tradeoff. The terms X^I and X^U denote the average portfolio choices of informed and uninformed traders. The uninformed trader's optimal holding of the risky asset is less than that of the informed trader because the uninformed trader faces greater risk in holding the asset.

such as the CAPM, traders know the same information, and if they have a common risk-aversion coefficient, hold the same market portfolio; this market portfolio is also mean-variance efficient. Here, traders disagree on the amount of each asset to hold. But it remains the case that in equilibrium the demands of the informed and uninformed must sum to the actual amount of assets in the economy, and so the market portfolio is defined by $x_k = (x_k)_{k=1}^k$. The following proposition shows that the market portfolio is mean-variance efficient with respect to average beliefs.

PROPOSITION 4: *The market portfolio is mean-variance efficient for average conditional beliefs:*

$$\bar{v}_k^M = \left(\mu_k \rho_k^I \bar{v}_k^I + (1-\mu_k)\rho_k^u \bar{v}_k^u\right)/\rho_k^M,$$
$$\rho_k^M = \mu_k \rho_k^I + (1-\mu_k)\rho_k^u.$$

Proof: See the Appendix.

Thus, the market also achieves mean-variance efficiency even though there is disagreement among the investors over this optimal tradeoff for individual

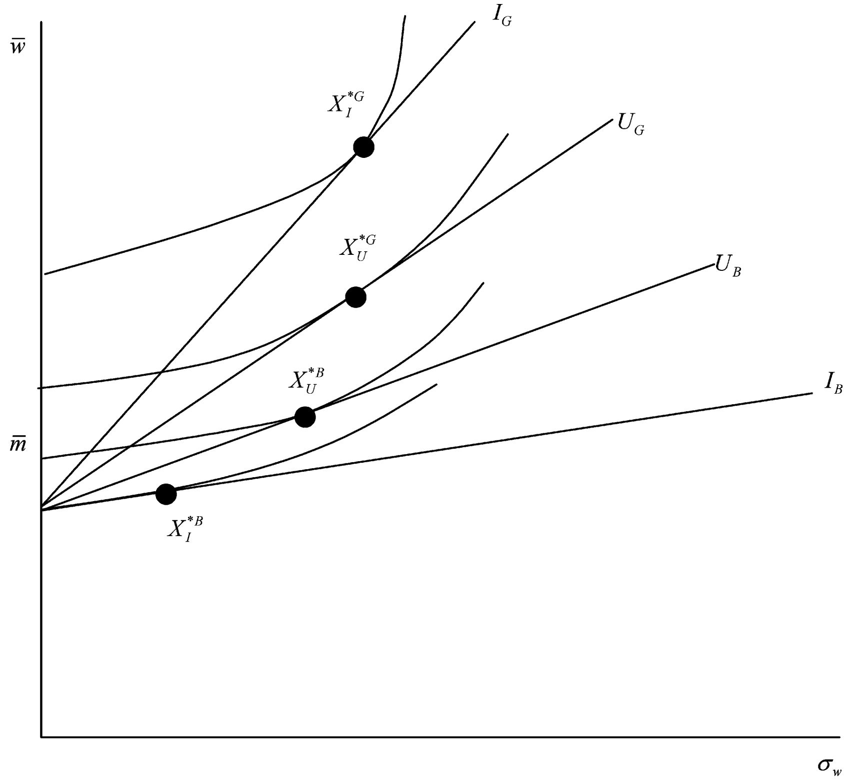

Figure 3. The effect of good and bad news on portfolios of informed and uninformed traders. This figure shows how the efficient frontiers change with respect to good and bad news for informed and uninformed traders. These efficient frontiers are given by I_G and I_B (U_G and U_B) for informed (uninformed) traders given good news and bad news, respectively. Informed traders' beliefs about mean return are more responsive to signals than are uninformed traders' beliefs. So when there is good news, the informed traders hold even more of the risky asset, and when there is bad news, their holdings are reduced by more than are the uninformed traders' holdings. If the news is bad enough, the informed hold less of the risky asset than do the uninformed.

assets. This result is reminiscent of Lintner's (1969) finding that with heterogeneous investors, the market portfolio is efficient with respect to the average belief across investors. In our asymmetric beliefs setting, this efficiency is defined as if there were a representative agent with CARA preferences, risk aversion δ, and beliefs $(\bar{v}_k^M, \rho_k^M)$. But there is, in fact, no such agent in the economy, and more importantly, it is not even possible to hold the market portfolio, as it depends on the (unobservable) realization of the random supply shock.

What investors do know is the average market portfolio, or simply the expectation $\bar{x}_k$. And investors could hold this average market portfolio should they choose to do so. Would this strategy remove the cross-sectional information effects we found in our equilibrium asset returns? That is, rather than try to pick assets in a world where others know more, would an uninformed investor be better off just holding this average portfolio in much the same way that all investors hold the market in CAPM? To address this question, we first need to show that this average market portfolio is mean-variance efficient.

PROPOSITION 5: *The average market portfolio $\bar{x}_k$ is mean-variance efficient with respect to unconditional means $(\bar{v}_k)$, prices $(\bar{p}_k)$ and ρ_k^M.*

Proof: See the Appendix.

Although the average market portfolio is mean-variance efficient with respect to some beliefs and prices, it is not optimal for any trader. To see this, we need only compute an investor's expected utility when he holds $(\bar{x}_k)$ and compare this to his utility when he holds the optimal portfolio (x_k^*). The difference in mean minus $\delta/2$ times variance for these portfolios is[17]

$$E[\bar{U}] - E[U^*] = \sum_{k=1}^{K} -\left(\bar{v}_k^j - p_k\right)\left(x_k^* - \bar{x}_k\right) + \frac{\delta}{2}\left(\rho_k^j\right)^{-1}\left[\left(x_k^*\right)^2 - (\bar{x}_k)^2\right] < 0. \quad (16)$$

To see that (16) is negative, note that it is maximized at $\bar{x}_k = x_k^*$, using x_k^* from (13).

A simple interpretation of equation (16) is that it measures how badly the CAPM does in an asymmetric information world. A trader holding the average market portfolio does worse than an uninformed trader who selects his asset holdings via standard maximization techniques. This divergence in performance increases with greater risk aversion, with more private information, and with greater aggregate supply shock randomness; it is tempered with greater precision of information. But this shortfall in performance should not be unexpected. If information is symmetric, there is nothing to be learned, and the market price is not informative. With asymmetric information, even uninformed traders learn, albeit imperfectly, from public information and from the equilibrium price function. Ignoring these data to hold an average portfolio cannot do as well.

D. Equilibrium Portfolios of Informed and Uninformed Investors

Another way to view this effect is to compute the equilibrium portfolios of informed and uninformed investors. Let Z_k^U be the per-capita demand for stock k by uninformed traders, and let Z_k^I be the per-capita demand for stock k by informed traders. Stocks are riskier for uninformed traders than they are for informed traders, and so one might expect this risk difference to affect how

[17] This is the difference of mean-variances. The difference in expected utilities is given by the increasing transformation, $-\exp(-\delta z)$, of the terms in (11).

much of any stock they hold. To determine this, we first calculate the difference in holdings of asset k by the informed and uninformed:

$$Z^I - Z^U = \left[\left(\sum_{i=1}^{\alpha_k I_k} s_i\right)\left(\gamma_k - \frac{\rho_{\theta k}}{\alpha_k I_k}\right) + p_k[\rho_{\theta k} - \alpha_k I_k \gamma_k] + \rho_{\theta k}\left(\frac{\delta}{\mu_k \gamma_k \alpha_k I_k}\right)(x_k - \bar{x}_k)\right]\delta^{-1}. \tag{17}$$

It is easy to see that $Z_k^I - Z_k^U$ is normally distributed with a strictly positive mean. Using this fact, we can calculate the difference in average holdings of asset k by the informed and uninformed, or

$$E\left[Z_k^I - Z_k^U\right] = \delta^{-1} E[\tilde{v}_k - p_k](\alpha_k I_k \gamma_k - \rho_{\theta k}) > 0. \tag{18}$$

The positive sign in equation (18) dictates that the informed investors are holding on average more of each risky asset than are the uninformed investors. How much more depends on the risk aversion coefficient, the expected return, the difference in precision of the informed and uninformed traders' information, and the model's structural parameters.

The potential magnitude of this effect can be illustrated in our numerical example. Specifying the parameter values as before ($I_k = 10$, $\mu_k = 0.2$, $\eta_k = \gamma_k = \rho_k = 1$, $\delta = 1$, $\overline{x_k} = 1$), we fix $\alpha_k = 0.5$. The optimal holdings of the informed and uninformed are determined by their demand functions and the equilibrium price, with the difference in these holdings given by equation (18). Solving for these informed and uninformed per-capita holdings yields $E[Z^I] = 1.27$ and $E[Z^U] = 0.73$. So on average, an informed trader holds almost 75% more of this asset than the uninformed trader holds, a nontrivial difference by any metric.

Returning to the model, an interesting question is how does the composition of information affect the average stock holdings of informed and uninformed investors? The composition of information is captured by α_k, or the fraction of signals that are private. Calculation shows

$$\frac{\partial E\left[Z_k^I - Z_k^u\right]}{\partial \alpha_k} > 0.$$

So if more of the information about asset k is private, then the difference between the average holdings of the informed and uninformed of asset k increases.

Again, the numerical example can illustrate this effect. Suppose we now let $\alpha_k = 0.8$ and we compare the resulting holdings with our base case holdings when $\alpha_k = 0.5$. Calculation shows that now $E[Z^I] = 1.49$ and $E[Z^U] = 0.51$. So now, on average an informed trader holds almost three times as much of this asset as the uninformed trader holds.

Earlier we argued that informed traders are able to capitalize on their private information by shifting their portfolios relative to those of the uninformed. This private news is captured by the sum of the private signals, $\sum_{i=1}^{\alpha_k I_k} s_i$, with good news raising this value and bad news lowering it. We can determine how private news affects the actual portfolios of informed and uninformed investors in the model by calculating

$$\frac{\partial\left(Z_k^I - Z_k^U\right)}{\partial \sum_{i=1}^{\alpha_k I_k} s_i} > 0. \tag{19}$$

Good private information raises the informed trader's holding of asset k relative to the uninformed, while bad private news has the opposite effect. Thus, while on average the informed hold more of the risky asset k than do the uninformed, their actual holding in any period will be more or less than the uninformed trader's holding, depending upon their specific private information.

How does the value of public information affect these portfolios? Because all traders see the public news, one might conjecture that it has no effect, but this is incorrect. To see why, note that the public information is $\sum_{i=\alpha_k I_k+1}^{I_k} s_i$. Again, positive public news raises this value, and negative public news lowers it. Computing the impact of public news on the holdings of the informed and uninformed, we find

$$\frac{\partial\left(Z_k^I - Z_k^U\right)}{\partial \sum_{i=\alpha_k I_k+1}^{I_k} s_i} < 0. \tag{20}$$

Thus, good public information lowers the holdings of asset k by informed traders, relative to the uninformed holdings. This occurs because good public news has more of a positive effect on the uninformed trader's beliefs than it does on the informed trader's beliefs. This induces the uninformed to hold relatively more of the asset, which closes the gap between the informed and uninformed holdings.

The portfolio changes induced by public and private news demonstrate the channel by which information affects cross-sectional asset returns. In the next section, we investigate this linkage in more detail by looking at the role played by the characteristics of public and private information.

IV. Information and the Cost of Capital

Our analysis thus far reveals that the distribution of private information affects the return investors require to hold any stock in equilibrium. Viewing this result from the perspective of the firm, a firm whose stock has relatively more private information and less public information thus faces a higher cost of equity capital.[18] We now turn to understanding the factors that increase or decrease this cost of capital.

[18] If we consider two firms that are identical except for the fraction of information that is private, we see that the equilibrium expected return per share is higher for the firm with more private information.

In our model, the dispersion of private information is captured by the variable μ_k, the fraction of traders who receive the private information. A higher value of μ_k, means that more traders know the information, and in equilibrium this influences the risk premium of the stock through two channels. First, the stock is less risky for informed traders than it is for uninformed traders. Thus, on average, informed traders hold greater amounts of the stock. So if more traders are informed, then on an average, demand for the stock increases, the price increases, and the firm's cost of capital falls. Second, there is an indirect effect on the cost of capital through the revelation of information by the stock price. If more traders are informed, then their information is revealed to the uninformed with greater precision. This makes the stock less risky for the uninformed and this further reduces the cost of capital.

These risk-premium effects are captured by the comparative static result

$$\frac{\partial E(\tilde{v}_k - \tilde{p}_k)}{\partial \mu_k} < 0. \tag{21}$$

This finding demonstrates that a greater dispersion of private information lowers the required risk premium, and thus lowers a company's cost of capital.

This theoretical result highlights the complex role that information plays in equilibrium. While the informed benefit from knowing private information, they also must contend with the fact that their own trades cause this information to be reflected in the stock price. The more informed agents there are, the more informative are their collective trades, and the more information is reflected in the equilibrium price. If all agents become informed, then as discussed in Proposition 3, all information is essentially public and there is no risk premium for private information.

These effects can be illustrated by our numerical example. Fixing the parameter values as before ($I_k = 10, \alpha_k = 0.5, \eta_k = \gamma_k = \rho_k = 1, \delta = 1, \overline{x_k} = 1$), we consider how changes in μ_k affect the risk premium. Table I, Panel B shows percentage changes in the company's required excess return generated by changes in μ_k. The example shows that this effect is nonlinear. Thus, when μ_k is small (say 0.2), increasing the fraction of informed traders ($\mu_k = 0.4$) generates a large change in the firm's required excess return; in our example, the percentage fall is on the order of 20%. When there are many informed traders ($\mu_k = 0.6$), increasing their representation in the population further (say to $\mu_k = 0.8$) has a smaller effect and generates a fall in the risk premium of less than 5%.

Taken together, our results on the existence and dispersion of information suggest that firms could lower their cost of capital either by reducing the extent of private information or by increasing its dispersion across traders. There are several potential ways of doing so. For example, firms could disclose information to the market that would otherwise be privately known. The optimal amount of disclosure by firms has been investigated by numerous authors in numerous contexts but our analysis here shows why this lowers the cost of capital: Substituting public for private information lowers the risk premium investors demand in equilibrium. Botosan (1997) provides empirical evidence for this effect by showing that for a sample of firms with low analyst following, greater disclosure reduces the cost of capital by an average of 28 basis points. Brown, Finn, and Hillegeist (2001) show that the quality of a firm's disclosures is negatively correlated with the level of information-based trade in its stock. This result, combined with the results of Easley et al. (2002), showing that the level of information-based trade directly affects the firm's cost of capital, demonstrates how disclosures affect the cost of capital.

It may be, however, that firms do not know the underlying private information, and so are unable to disclose it to the market. Alternatively, even if they do know it, the moral hazard problems of self-reporting information may lead the market to be doubtful of any such disclosures. But firms can encourage greater scrutiny of the company by financial analysts, who may aid in both the development and dissemination of information.[19] It is also in the company's best interest to increase the quality of the information about the firm. Returning to the risk premium in Proposition 2, it is straightforward to show that the precision of both public and private information affects the required return, or

$$\frac{\partial E(\tilde{v}_k - p_k)}{\partial \gamma_k} < 0. \tag{22}$$

Returning to the numerical example, we can investigate this effect by considering how changes in γ_k affect the firm's excess risk premium. Table I, Panel C shows that the quality of information exerts a large effect on the risk premium. Thus, increasing the precision of information from $\gamma_k = 0.8$ to $\gamma_k = 0.9$ reduces the risk premium by more than 10%. When information precision is already high, increasing γ_k has a smaller, but still significant effect on the risk premium.

This finding reinforces the role played by analysts in affecting asset returns. The forecast of any one analyst may have low precision, but the collective forecast of many analysts should be much more accurate. Thus, companies benefit from having many analysts because analysts increase the precision of information and this lowers the companies' cost of capital.

These findings suggest an important role for the accuracy of accounting information in asset pricing. Here, greater precision directly lowers a company's cost of capital because it reduces the riskiness of the asset to the uninformed. This finding is consistent with the extensive accounting literature documenting the effects of accounting treatments on stock prices. Given that accounting changes do not affect the company's underlying business or economic profits, standard asset-pricing models would not suggest any impact on stock prices. Our model demonstrates why this reasoning is wrong; because information affects asset prices, the quantity and quality of that information is very relevant for asset-price behavior.

[19] Whether analysts actually uncover new information, or simply disseminate what is already known to at least some traders, is a subject of debate. Note, however, that in our model just disseminating information would increase μ_k, and this would lower the firm's cost of capital. For a discussion of information and analysts, see Easley, O'Hara, and Paperman (1998).

An interesting feature of our model is that the life cycle of a firm may also influence its cost of capital. In particular, it seems reasonable that a firm with a long operating history will be better known by investors. This is captured in our model by the prior belief that investors will have a greater prior precision if they know more about the firm. In our model, the precision of the prior belief has a direct effect on the risk premium given by

$$\frac{\partial E(\tilde{v}_k - p_k)}{\partial \rho_k} < 0. \tag{23}$$

Thus, the greater the prior precision, the lower the cost of capital. This finding is consistent with the oft-observed regularity that more established firms find it easier and cheaper to raise funds in the market.

This finding is also consistent with the empirical results of Coval and Moskowitz (1999) and Huberman (2001), who find that money managers and investors are more comfortable holding "local" stocks, that is, stocks with which they are more familiar. In our setting, local investors may feel that they have greater prior precision about local companies, and thus they require less of a risk premium to hold such assets.[20]

What about firms who are at the other end of the spectrum, the firms who are entering the market for the first time? Certainly, the effect in equation (22) would suggest that the low prior precision on those firms would increase the cost they face in raising capital.[21] But these firms face other problems as well. In particular, it may be that for some firms, there is little public information available. In our analysis thus far, we have considered the cross-sectional differences that arise when firms have the same total amount of information, but the composition of information between public and private sources may differ. For new firms, however, it seems likely that there is less information overall, and that what information exists is more likely to be private. How then does this affect the cost of capital?

One way to address this question is to consider the role of private information in isolation. That is, if there were no public information, would a firm be better off having some private information or no private information? Proposition 6 demonstrates that having information is always better than not having information.

[20] Such geographical preferences may also lend insight into the well-known phenomena of home country bias. If domestic investors feel that they have greater prior precision for domestic stocks, then they may view domestic stocks as having a lower risk-return trade-off than they face with foreign stocks. See Brennan and Cao (1997) for an analysis of this effect.

[21] Since most new firms are also small firms, this effect would also be consistent with the empirical regularity that small firms' returns are higher than would be predicted by a standard CAPM. Indeed, Ibbotson Associates (2000, p. 141) notes that "Based on historical return data on NYSE decile portfolios, the smaller deciles have had returns that are not fully explained by the CAPM. This return in excess of CAPM grows larger as one moves from the largest companies to the smallest." Such an effect could be explained by the information issues we highlight here.

PROPOSITION 6: *Suppose $\alpha_k = 1$. Then, for any firm k,*

$$\frac{\partial E\,(\tilde{v}_k - p_k)}{\partial I_k} < 0.$$

Proof: See the Appendix.

The result in Proposition 6 may appear to be paradoxical; in a world with no public information, having some private information lowers a firm's cost of capital relative to what it would be if there were no private information. One might have conjectured that uninformed investors would prefer a stock with no informed traders, but this is not the case. This is because of the effect that information has on the asset's equilibrium price. When some traders are informed, this price is more informative, and this lowers the risk for the uninformed. Of course, the risk and thus the firm's cost of capital is even lower if the information is public (this is our finding in Proposition 3). But given the choice of no information, or only private information, the firm's cost of capital is lower in a world in which someone knows something.

This distinction between the existence of information in general, and the distribution of private and public information in particular, provides a way to reconcile our findings with those of previous models of the effects of information on asset prices. In a model with one risky and one riskless asset, Wang (1993) found that private information did not generally result in a risk premium for the risky asset. This finding is consistent with the intuition behind Proposition 6, in which some information is better than none. In our model, with many assets and public and private information, we find that there is a risk premium, and that it varies within the cross section of stocks. These cross-sectional effects arise because of the portfolio channel discussed earlier. In general, one would expect that both effects would be present to some extent, but in any multiasset world these cross-sectional effects will be present.

This dichotomous role of information may also explain the impact of insider trading laws on a company's cost of capital. The Manne's (1966) argument against insider trading prohibitions essentially viewed some information, even if it were private, as better than no information at all (again our Proposition 6 result). Bhattacharya and Daouk (2002), in a comprehensive empirical study of 103 countries, however, estimate that the enforcement of insider trading prohibitions reduces the cost of capital by between 0.3% and 6.0%. Assuming that the effect of these laws is to turn at least some of the private information into public information, then this effect is predicted by our model: Reducing the risk of informed trading, and correspondingly increasing the amount of public information, reduces the risk premium uninformed traders demand to hold the stock.[22]

[22] This argument assumes that the total amount of information is held constant. If enforcement of insider trading laws changes the amount of information produced, other effects need to be considered.

Finally, we consider one other effect on the company's cost of capital. As shown in Proposition 2, the level of risk aversion enters into the determination of the risk premium. The risk aversion level is not stock specific, and so it is not within the purview of a company to influence it. However, it is straightforward to show that increases in the risk-aversion parameter directly increase the risk premium demanded by investors.

This has two implications for our analysis. First, if the level of risk aversion changes over time, then we might expect to find the dispersion of cross-sectional returns changing as well. This occurs because investors need even greater compensation to hold stocks with more private information when the risk-aversion parameter increases, and conversely they need less compensation when it falls. Such changes in cross-sectional return dispersion seem consistent with actual asset-price behavior. Second, if risk aversion is time varying, then this may explain the cycles we observe in firms coming to market. It is well known that IPOs exhibit a "feast or famine" cycle, with firms typically clustering together in coming to market. Since IPO firms have greater private information and low information precision overall, our model would predict a high risk premium to induce investors to hold them. An increase in overall risk aversion will cause this premium to increase even more, thereby inducing some firms to wait for the "better market conditions" consistent with a lower risk-aversion level.

V. Extensions and Generalizations

In this paper we use a simple rational expectations model to make our arguments. A natural concern is that the simplicity of the model, while useful for illustrative purposes, is chimerical; perhaps in a fuller model, the results we are interested in would no longer hold. In this section, we address this issue by considering how some extensions and generalizations to the model affect our results.

A. Multiperiod Effects

The model here incorporates two periods, today and tomorrow. Allowing for multiple periods complicates the analysis, but for at least some reasonable specifications does not affect our results. For example, it is fairly straightforward to demonstrate that if new information arrives every period and information is independent across periods, then our results are unchanged. In this world, agents essentially solve the same decision problem period after period that they solve here, and so the resulting equilibrium remains the same.

This need not be true for every information structure. If private information once revealed now reduces permanently the private information over the *lifetime* of a stock, then one could get the paradoxical result that high information stocks are less risky to hold, since the risk decreases over time faster than the risk of low information stocks decreases. Again, while it is conceptually possible, we do not find this economically plausible. To the extent that information revealed today reduces information asymmetry tomorrow, then we would expect this to diminish but not remove the effects outlined here.

B. Interpretations of the Asset Structure

The asset structure we analyze results in some asset-specific risks being less than completely diversifiable. Such an outcome also arises in asset-pricing models in which factors such as HML (the book-to-market effect) or size are priced. What allows those risks and the information risk we derive here to be priced is simply that agents must be compensated for risk, and the asset structure is not sufficient to remove the risk.[23] While this incompleteness can arise naturally from the nature of the assets in the economy, it can also arise if some investors are constrained in the assets that they can hold. Such participation constraints motivate Merton's (1987) analysis of asset pricing with incomplete information about the set of available assets. This idea has since been explored extensively by several authors including Basak and Cuoco (1998) and Shapiro (2002). A similar limited participation explanation is used to explain the results on home bias in asset portfolios (see, for example, Stulz (1981)). While we do not use a participation argument here, such a constraint could also result in information risks being priced.

C. Endogenous Information Acquisition

In our analysis, the fraction of the investing population that is informed and the number of signals that they observe are given exogenously. Many of our conclusions are generated from comparative statics results about these variables. An alternative approach would be to allow investors to choose whether to become informed or not, or more generally, to choose the number of signals they observe. Given some cost of becoming informed, or some cost per signal, the equilibrium fraction of informed investors or the number of signals observed per investor could be derived. The relevant comparative statics results would then be about the effect of the cost of information on the cost of capital.

We believe that this would be an interesting alternative approach, but we have not carried it out here for three reasons. First, it is not clear to us how to model the market for information. Assuming that individuals buy information in a competitive market at some fixed price pretends that the market for information is like any other competitive market, in which the good is competitively supplied and in which only purchasers have access to the good. But information can be both consumed and given away. Alternatively, one could view the cost of information as the value of the time it takes an investor to collect and interpret information. These costs surely differ across investors. Second, we believe that these costs differ so much that assuming investors to be informed or not is a reasonable approximation. Some investors, perhaps insiders and institutions,

[23] Fama and French (1992), for example, argue that HML and size proxy for firm risk sensitivities to factors such as distress risk.

are always more informed than the typical retail trader, who could not become informed at any reasonable cost. Third, in order to decide whether to become informed about a stock, an investor has to compute the ex ante value of his equilibrium decision problem when he is informed or not. When there is no excess return on assets, this is straightforward; it is much more complex when there are excess returns. This added complexity makes closed-form solutions difficult to obtain and in our opinion detracts from the point of our analysis.

VI. Conclusions

We have developed an asset-pricing model in which both public and private information affect asset returns. Because the return investors demand determines a firm's cost of equity capital, our analysis provides the linkage between a firm's information structure and its cost of capital. We have demonstrated that investors demand a higher return to hold stocks with greater private information. This higher return reflects the fact that private information increases the risk to uninformed investors of holding the stock, because informed investors are better able to shift their portfolio weights to incorporate new information. Private information thus induces a form of systematic risk, and in equilibrium investors require compensation for bearing this risk.

An important implication of our research is that firms can influence their cost of capital by affecting the precision and quantity of information available to investors. This can be accomplished by a firm's selection of its accounting standards, as well as through its corporate disclosure policies. Attracting an active analyst following for a company can also reduce a company's cost of capital, at least to the extent that analysts provide credible information about the company. Yet another way to influence its information structure is through the firm's choice of where to list their securities for trading. Because investors learn from prices, the microstructure of where a firm's securities trade can influence how well and how quickly new information is reflected in the stock price. These factors suggest that a firm's cost of capital is determined, at least partially, by corporate decisions unrelated to its product market decisions.

Our findings here raise a number of issues for further study. If, as our analysis suggests, the quality of information affects asset pricing, then how information is provided to the markets is clearly important. Recently, the SEC has considered allowing individual investors access to IPO electronic road shows, has proposed tighter restrictions on what companies can disclose privately to analysts, and has pondered whether internet investment chat rooms are positive or negative influences for stock prices. While addressing each of these topics is beyond our focus here, the framework we develop does provide a way to consider how particular market practices affect equilibrium asset pricing. Our results also raise interesting questions about security market design and the cost of capital. In particular, how transparency of trades and orders influence the informativeness of stock prices, or even how the speed of the trading system affects information flows to investors, seem important directions for future research.

Appendix

Proof of Proposition 1: It is sufficient to show that there is a solution to the market clearing equation (14) of the form given in the statement of the proposition. Substituting into (14) for demand by informed and uninformed traders gives

$$\mu_k \left[\frac{\rho_k \bar{v}_k + \gamma_k \sum_{i=1}^{I_k} s_{ki} - p_k(\rho_k + \gamma_k I_k)}{\delta} \right]$$

$$+ (1-\mu_k) \left[\frac{\rho_v \bar{v}_k + \gamma_k \sum_{i=\alpha_k I_k + 1}^{I_k} s_{ki} + \rho_{\theta k}\theta_k - p_k(\rho_k + \gamma_k(1-\alpha_k)I_k + \rho_{\theta k})}{\delta} \right] = x_k. \tag{A1}$$

So,

$$p_k = \frac{\rho_k \bar{v}_k + \gamma_k \sum_{i=\alpha_k I_k + 1}^{I_k} s_{ki} + \mu_k \gamma_k \sum_{i=1}^{\alpha_k I_k} s_{ki} + (1-\mu_k)\rho_{\theta k}\theta_k - \delta x_k}{\rho_k + \gamma_k(1-\mu_k)I_k + \mu_k \alpha_k \gamma_k I_k + (1-\mu_k)\rho_{\theta k}}. \tag{A2}$$

Both θ_k and $\rho_{\theta k}$ involve coefficients from the conjectured price equation (9) in the form of $(\frac{d}{b})$. Substituting in for θ_k in (A2) from (10) and simplifying shows that

$$\frac{d}{b} = \frac{\delta}{\mu_k \gamma_k}.$$

So by (10) and (11)

$$\rho_{\theta k} = \left[(\mu_k \gamma_k \alpha_k I_k)^{-2} \eta_k^{-1} \delta^2 + (\alpha_k I_k \gamma_k)^{-1} \right]^{-1}, \tag{A3}$$

and

$$\theta_k = \frac{\sum_{i=1}^{\alpha_k I_k} s_{ki}}{\alpha_k I_k} - \left(\frac{\delta}{\mu_k \gamma_k \alpha_k I_k} \right)(x_k - \bar{x}_k). \tag{A4}$$

Substituting (A3) and (A4) into (A2) and solving for the coefficients yields the price equation and coefficients given in the proposition. This equation is of the conjectured form (9) so it is a rational expectations equilibrium.

Proof of Proposition 2: The expected return on stock k is, by Proposition 1,

$$E[v_k - p_k] = E\left[v_k - a\bar{v}_k - b\sum_{i=1}^{\alpha_k I_k} s_{ki} - c\sum_{i=\alpha_k I_k+1}^{I_k} s_{ki} + dx_k - e\bar{x}_k\right]. \quad \text{(A5)}$$

The mean of each s_{ki} is $\bar{v}_k$ and the mean of x_k is $\bar{x}_k$, so

$$E[v_k - p_k] = \bar{v}_k[1 - a - b\alpha_k I_k - c(1-\alpha_k)I_k] + \bar{x}_k(d - e). \quad \text{(A6)}$$

Using the coefficients from Proposition 1, computation shows that $1 - a - b\alpha_k I_k - c(1-\alpha_k)I_k = 0$ and that $d - e = \delta/C_k$. Thus

$$E[v_k - p_k] = \frac{\delta\bar{x}_k}{\rho_k + (1-\alpha_k)I_k\gamma_k + \mu_k\alpha_k I_k\gamma_k + (1-\mu_k)\rho_{\theta k}}. \quad \text{(A7)}$$

Proof of Proposition 3: Using the result of Proposition 2, calculation shows that

$$\frac{\partial E[v_k - p_k]}{\partial\alpha_k} = \frac{\delta\bar{x}_k(1-\mu_k)}{(C_k)^2}\left[I_k\gamma_k - \frac{\partial\rho_{\theta k}}{\partial\alpha_k}\right]. \quad \text{(A8)}$$

Then

$$\frac{\partial\rho_{\theta k}}{\partial\alpha_k} = \frac{I_k\gamma_k\left(2\alpha_k^{-1}\mu_k^{-2}I_k^{-1}\gamma_k^{-1}\eta_k^{-1}\delta^2 + 1\right)}{\left(\mu_k^{-2}\alpha_k^{-1}I_k^{-1}\gamma_k^{-1}\eta_k^{-1}\delta^2 + 1\right)^2}. \quad \text{(A9)}$$

So

$$I_k\gamma_k - \frac{\partial\rho_{\theta k}}{\partial\alpha_k} = I_k\gamma_k\left(1 + \alpha_k I_k\eta_k\mu_k^2\gamma_k\delta^{-2}\right)^{-2}. \quad \text{(A10)}$$

Thus

$$\frac{\partial E[v_k - p_k]}{\partial\alpha_k} = \frac{\delta\bar{x}_k(1-\mu_k)I_k\gamma_k}{(C_k)^2\left(1 + \alpha_k I_k\eta_k\mu_k^2\gamma_k\delta^{-2}\right)^2} > 0. \quad \text{(A11)}$$

Proof of Proposition 4: The future wealth from a portfolio of stocks $z = (z_1, \ldots, z_k)$ is $\tilde{w} = \sum_k(\tilde{v}_k - p_k)z_k$, where $\tilde{v}_k$ is normally distributed with some mean $\bar{v}_k^m$ and precision ρ_k^m. Given beliefs $(\bar{v}_k^m, \rho_k^m)_{k=1}^K$, the portfolio $(z_k^*)_{k=1}^K$ is mean-variance efficient if it solves

$$\underset{(z_k)}{MAX}\sum_k(\bar{v}_k^m - p_k)z_k - \frac{\lambda}{2}\sum_k\left(\rho_k^m\right)^{-1}z_k^2 \quad \text{(A12)}$$

for some $\lambda > 0$.

The solution is

$$z_k^* = \frac{\bar{v}_k^m - p_k}{\lambda\left(\rho_k^m\right)^{-1}} \tag{A13}$$

The equilibrium prices $(p_k)_{k=1}^k$ in Proposition 1 can be rewritten as

$$p_k = \frac{\mu_k \rho_k^I \bar{v}_k^I + (1-\mu_k)\rho_k^U \bar{v}_k^U - \delta x_k}{\mu_k \rho_k^I + (1-\mu_k)\rho_k^U} = \bar{v}_k^m - \frac{\delta x_k}{\rho_k^m}, \tag{A14}$$

where $(\bar{v}_k^I, \rho_k^I)$ are beliefs of the informed traders given in (7) and (8), and $(\bar{v}_k^U, \rho_k^U)$ are beliefs of the uninformed traders given in (12) and (13).

Substituting equilibrium prices into (A13) and using the definition of average beliefs $(\bar{v}_k^m, \rho_k^m)$, we have

$$z_k^* = \left(\frac{\delta}{\lambda}\right) x_k. \tag{A15}$$

Letting $\lambda = \delta$, we see that the market portfolio $(x_k)_{k=1}^k$ is mean-variance efficient.

Proof of Proposition 5: Unconditional prices are

$$\bar{p}_k = \bar{v}_k - \frac{\bar{x}_k \delta}{\rho_k^m}. \tag{A16}$$

By the argument in the proof of Proposition 4, $(\bar{x}_k)_{k=1}^k$ will be mean-variance efficient for prices $(\bar{p}_k)_{k=1}^k$ and beliefs $(\bar{v}_k, \rho_k^m)_{k=1}^k$ if

$$\bar{x}_k = \frac{\bar{v}_k - \bar{p}_k}{\lambda\left(\rho_k^m\right)^{-1}} \tag{A17}$$

for some λ.

Substituting in unconditional prices, we have

$$\bar{x}_k = \left(\frac{\delta}{\lambda}\right) \bar{x}_k. \tag{A18}$$

Letting $\lambda = \delta$, we see that $(\bar{x}_k)$ is mean-variance efficient.

Proof of Proposition 6: Using the form of the expected return from Proposition 2, calculation shows that at $\alpha_k = 1$,

$$\frac{\partial E[v_k - p_k]}{\partial I_k} = -\frac{\delta \bar{x}_k}{(C_k)^2}\left(\mu_k \gamma_k + (1-\mu_k)\frac{\partial \rho_{\theta k}}{\partial I_k}\right) \tag{A19}$$

and

$$\frac{\partial \rho_{\theta k}}{\partial I_k} = \frac{2 I_k^{-3}(\mu_k \gamma_k)^{-2}\eta_k^{-1}\delta^2 + I_k^{-2}(\gamma_k)^{-1}}{((\mu_k \gamma_k I_k)^{-2}\eta_k^{-1}\delta^2 + (I_k \gamma_k)^{-1})^2} > 0. \tag{A20}$$

So

$$\frac{\partial E\left[v_k - p_k\right]}{\partial I_k} < 0. \tag{A21}$$

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