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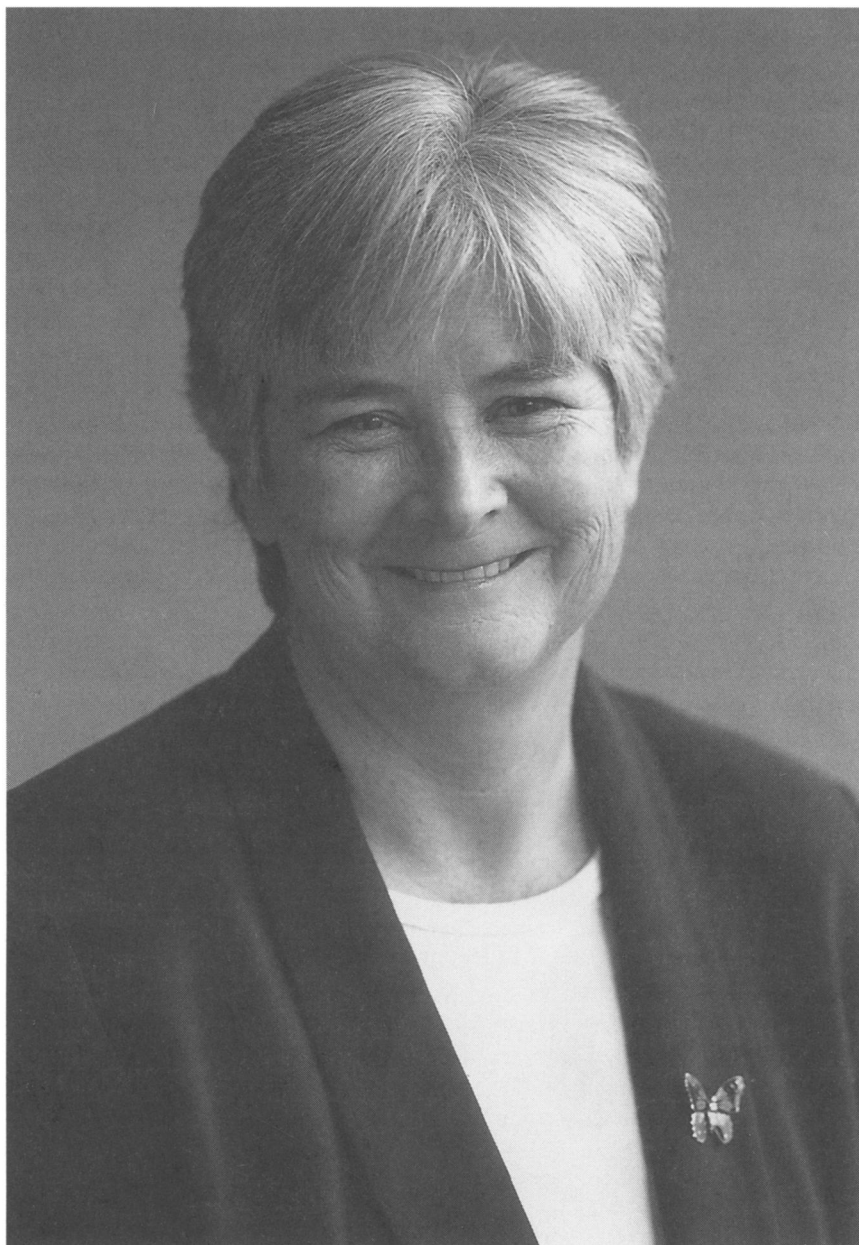
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ABSTRACT

This paper examines the implications of market microstructure for asset pricing. I argue that asset pricing ignores the central fact that asset prices evolve in markets. Markets provide liquidity and price discovery, and I argue that asset pricing models need to be recast in broader terms to incorporate the transactions costs of liquidity and the risks of price discovery. I argue that symmetric information-based asset pricing models do not work because they assume that the underlying problems of liquidity and price discovery have been solved. I develop an asymmetric information asset pricing model that incorporates these effects.

THIS PAPER EXAMINES THE IMPLICATIONS of market microstructure for asset pricing. Both research areas focus on the behavior and evolution of asset prices, but the microstructure implications have been largely missing from the asset pricing literature. Such an omission is unimportant if asset pricing models work well in the sense of explaining the observed behavior of asset prices, but this is not the case. The proliferation of anomalies, momentum, and the changing cast of factors needed to explain even partially the behavior of asset prices all suggest that success is not yet within our grasp.

I will argue in this paper that asset pricing ignores the central fact that market microstructure focuses on: Asset prices evolve in markets. Markets have two important functions—liquidity and price discovery—and these functions are important for asset pricing.[1] I will link these two concepts to our more basic constructs of risk and expected return, and I will suggest that asset pricing models need to be recast in broader terms to incorporate the transactions costs of liquidity and the risks of price discovery. I will argue that information is not symmetric nor is equilibrium revealing. The symmetric information-based asset pricing models do not work because they assume that the underlying problems of liquidity and price discovery have been completely solved. I suggest a different asset pricing framework of asymmetric information that requires rethinking

[1] These market functions, in turn, allow markets to play many different roles, among them that of allowing individuals to reallocate their asset holdings. This allocational a role results in risk sharing among investors, something that also may affect asset prices.

Maureen O'Hara
President of the American Finance Association
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the role of uninformed traders—the infamous noise traders of years past. My talk will draw heavily on my work on these topics with David Easley (see, e.g., Easley and O'Hara (2001)). Thus, my ideas here are really better viewed as a joint product (with the good ideas clearly evolving from my coauthor, as has so often been the case).

Some might argue that what I propose is simply wrong because it is inconsistent with traditional CAPM. Others will assert that it is technically correct, but practically unimportant. I think both objections are incorrect, but as they say, the proof is in the pudding. I will end with examples of how this information-based approach has implications for the cross section of expected returns, the equity premium puzzle, and the concept of market efficiency.

I. Asset Price Formation

Consider the standard economics explanations of how asset prices emerge. The basic Walrasian story abstracts from the actual mechanics of markets. Instead, traders turn in demands to the fictitious auctioneer who aggregates the traders' buy and sell desires. The auctioneer then sets a price to clear markets. Demands depend upon consumption decisions, so asset prices reflect these consumption decisions as well. This is a symmetric information story—all traders share the same information regarding the asset's expected risk and return. Note that in this world, buyers and sellers are all present at the same time, so the auctioneer need only aggregate the expressed trading desires to find the equilibrium price.

Now introduce information asymmetries. The Grossman–Stiglitz (1980) model and critique provides the starting point for this analysis. In the simple version of this world, the informed traders know more than the uninformed; the uninformed know there are informed traders but not what they know; the uninformed make inferences about this information from the price; everyone turns in demands (to the auctioneer); and the equilibrium price emerges. If the equilibrium is fully revealing, then the uninformed learn the information from the equilibrium price, and symmetric information characterizes the market. We are now back in the world depicted above, where all traders face the same decision problems, but where the informed have no incentive to gather information (the Grossman–Stiglitz critique).

Asset pricing models typically start from here—symmetric information. The CAPM, the APT, and the consumption-based CAPM all assume symmetric information.[2] A rationalization for this is simply to argue that we characterize asset

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[2] An exception is the Merton (1987) model that assumes incomplete information. The distinctions between the incomplete and asymmetric information worlds will be addressed shortly, but it is useful to note here that the incomplete information models do not allow traders to learn from the market price. Thus, prices play only an allocational role, and not the informational role that I argue will be important for asset pricing.

prices *as if* markets are in symmetric information equilibrium. But this is clearly a caricature—we know it is not right for individual assets, and it seems equally implausible for the market as a whole. Over time, *as if* became *as is*, and asset pricing models were based on the notion that asset prices could be viewed as arising from a symmetric information world. One justification given for this is that information only matters for the market as a whole; individual stock risk, the idiosyncratic risk, can be diversified away. So even if the symmetric framework isn't true, this problem doesn't matter: Hold enough stocks and the world seems symmetric.

But there are some obvious problems here. An immediate one is that the expected risk–return trade-off envisioned here requires computing the market's expectation. Even in a symmetric information world, this can be challenging if the underlying process generating asset returns is complex. Thus, research by Brennan (1998), Brennan and Xia (2000, 2002), Xia (2001), and Lewellen and Shanken (2002) considers how one determines the risk-return trade-off in the presence of model uncertainty, parameter uncertainty, and learning risk (but all of it in a symmetric information world). But what if we don't all know the same thing? If there is differential information, whose expectation are we calculating? Lintner raised this concern in his 1969 paper, and Ned Elton (1999) discussed the important empirical implications of this in his presidential address.

Alternatively, it may be that a nonrevealing equilibrium emerges, and prices do not level the playing field between traders. Informed traders can now profit from their information, and so their paradox of earning a return from their information-gathering efforts disappears. But now the problem is with the uninformed traders, who are losing what the informed are gaining. The solution here is noise traders. These traders, and the concept itself, rescue the story. As Fischer Black (1986) pointed out in his presidential address, it is noise that allows markets to function.

But these noise traders always lose, raising the obvious question: Why are they so stupid? One explanation can arise from the research in behavioral finance. Overconfidence, mistakes in updating, prospect theory, and framing issues all can explain why it is that traders remain so docile (or deluded).[3] Alternatively, these same factors may influence the informed traders' behavior, providing the opening that the uninformed need to remain "in the game." These behaviors will lead to asset prices that do not behave as predicted by symmetric information models, and so may accord better with observed asset prices. I am sympathetic to the ideas developed by my behavioral colleagues, and I suspect that they will prove useful in expanding our understanding of asset price behavior.

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[3] Shleifer and Summers (1990) provide an excellent overview of the noise trader approach to asset pricing. They note that "Our approach rests on two assumptions. First, some investors are not fully rational and their demand for risky assets is affected by their beliefs or sentiments that are not fully justified by fundamental news. Second, arbitrage—defined as trading by fully rational investors not subject to such sentiment—is risky and therefore limited" (p. 19).

More compelling to me, however, is that it is not noise that makes markets work, but rather that uninformed traders are smarter than we have allowed: They recognize risk and they want compensation for bearing it.[4] These uninformed traders know they will lose to better informed agents, but they have portfolio choices to make, and these choices allow them to choose assets in which their risk of losing to better informed traders is lower. Information risk matters, and so, too, does the process by which information enters asset prices. And this sets the stage for the role of markets in asset pricing.

II. Asymmetric Information, Asset Prices, and the Role of Markets

Markets provide liquidity and price discovery. These two concepts are related, but they are not the same. As each function can influence asset prices, I first discuss how liquidity enters into asset price formation, and then turn to the impact of the price discovery process on asset price behavior.

Liquidity refers to the matching of buyers and sellers. It is intertemporal in nature and it is not necessarily linked to price discovery. As a simple example of this distinction, suppose that all buyers of an asset arrive on Monday and all sellers on Tuesday. The buyers and sellers may all agree on the "fundamental value" of the asset, but in this illiquid world, the concept of a market price is not well defined. No trade will take place on Monday in the absence of sellers, and unless the buyers stick around until the next day, no trade will occur on Tuesday either. In this world, a role emerges for a market intermediary who will sell to the buyers on Monday and buy from the sellers on Tuesday. For providing this liquidity, a spread emerges between the buying and selling prices to compensate the middleman. This notion of liquidity production was applied by Demsetz (1968) to explain the behavior of stock exchange specialists, and it has been expanded by a legion of authors (Garman (1976), Stoll (1978), Ho and Stoll (1981), Amihud and Mendelson (1986, 1988), O'Hara and Oldfield (1986), Grossman and Miller (1988), Biais (1993), and Madhavan and Smidt (1993), to name but a few) to a wide range of issues in market microstructure.

This liquidity-based spread is a transactions cost for traders. Can this cost affect asset prices more generally? The asset pricing literature and the microstructure literature diverge on this point. There is a long literature in asset pricing looking at the role of transactions costs (see, e.g., Constantinides (1986), Aiyagari and Gertler (1991), Heaton and Lucas (1996), Vayanos (1998), and Vayanos and Vila (1999)). In general, these authors argue that liquidity costs can only have a second-order effect on the level of asset prices because transactions cost are just

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[4] One argument for limiting the trading motivations of uninformed traders has been the Milgrom–Stokey (1982) critique that because the uninformed always lose to the informed, rationality requires that the uninformed only trade for nonspeculative purposes, or simply not trade at all. If markets are not complete, however, then the arrival of information to some traders changes the risk–return trade-off for all traders. Because new risk-sharing opportunities arise, the uninformed are not trading for purely speculative purposes—they can and must trade, if they are rational.

too small relative to the equilibrium risk premium to matter.[5] The counter argument was originally put forth by Amihud and Mendelson (1986, 1988) and subsequently expanded by numerous authors (see Brennan and Subrahmanyam (1996), Brennan, Chordia, and Subrahmanyam (1998), Chalmers and Kadlec (1998), Chordia, Roll, and Subrahmanyam (2000), Pastor and Stambaugh (2001), and Amihud (2002)). These authors argue that empirically, asset prices do reflect liquidity costs, with studies linking asset price behavior to a variety of liquidity measures such as spreads, depths, and volumes.

In this context, liquidity is akin to a tax or a cost borne by investors. It seems to me that if these costs are large enough, they should negatively affect asset prices because of their effect on net asset returns.[6] In the same vein, reducing these costs through, for example, the introduction of a more efficient trading mechanism should have an immediate positive effect on an asset's value.[7] The microstructure of the market influences these liquidity costs, and so if the effects are large enough, microstructure and liquidity affect asset returns.

Can liquidity also affect the risk of holding an asset? Here the issue is more complex, as liquidity would then have to be time varying, or at least be systematic in some sense. There is a growing literature addressing this issue, with Chordia et al. (2000), Huberman and Halka (2001), and Amihud (2002) arguing that there are systematic factors here, while Hasbrouck and Seppi (2001) find the opposite. Whether liquidity is a risk remains contentious, in part because it is unclear what would generate commonality in liquidity. And even if such commonality exists, it may be diversifiable across asset classes.[8] This would suggest only a secondary role for liquidity in affecting an asset's risk.

But this is not the case for the other function of markets, price discovery. Price discovery involves the incorporation of new information into asset prices, and it requires that we consider again the role of the informed and uninformed traders. For reasons given earlier, I will focus on partially revealing rational expectations

[5] Huang (2001) agrees that in general this is true, but that it need not be the case if traders are constrained from borrowing against their future income stream. Holmstrom and Tirole (2001) develop a related firm-based argument in which firms demand liquidity to meet future cash needs. In this model, assets from expected returns can be affected by their covariance with market liquidity.

[6] Try selling a pony—this is a real cost! Indeed, for many classes of assets, the transactions cost of locating buyers and sellers has a significant influence on asset value.

[7] Thus, a number of researchers have found price effects for securities moving from one trading mechanism to another (see, e.g., Christie and Huang (1994) or Bessembinder (2003) on securities moving from the Nasdaq to the NYSE) or when exchanges move securities from one trading platform to another (see Amihud, Mendelson, and Lauterbach (2003)). An interesting recent example of this liquidity effect is the rise of electronic markets such as Ebay. It is now commonplace for traditionally illiquid assets such as antiques to trade on Ebay, creating a meeting place for buyers and sellers. For at least some assets (such as antique Ithaca Calendar Clocks) the result has been a more active market and a more valuable asset.

[8] In particular, if some event causes a liquidity problem in one market, it may induce a corresponding liquidity inflow in another market. Examples of this could be the "flight to quality" observed periodically in the bond markets or in the markets for emerging market debt. For an interesting analysis of liquidity linkages between stock and bond markets, see Chordia, Sarkar, and Subrahmanyam (2002).

equilibria, or the process of price adjustment. Information creates a risk for uninformed traders as the trading gains of the informed arise from the trading losses of the uninformed. Can the uninformed diversify away this risk? To a degree they can, but the presence of asymmetric information thwarts the effectiveness of a diversification strategy. If, as is standard in microstructure analyses, the uninformed (or noise traders) are always uninformed, then they lose, to varying degrees, to the informed in every risky asset they hold. In effect, holding more assets simply cumulates these losses, rather than dissipates the risk, as occurs in symmetric information settings.

What is the problem here? Why doesn't the standard trick of holding the market portfolio remove this risk? The difficulty is that the informed and the uninformed will not hold the same portfolio. All investors know the assets in the market, but not the weights to hold in the portfolio. How much to hold depends upon the equilibrium value of the asset, but in a nonrevealing equilibrium, the informed and the uninformed will have different beliefs about what this should be. Informed investors will shift their portfolios to hold more of the "good" assets and less of the "bad" assets. The uninformed investors cannot know which assets to under- or overweight, and in equilibrium, they end up with too much of the bad assets and too little of the good ones.[9] This disparity in portfolio holdings is greatest for assets with the largest informational disadvantage, suggesting that the uninformed face differential risks across assets.

A simple example can illustrate this problem. Suppose your goal is simply to "hold the market," and you do so by holding shares of companies in the Russell 1000. How much of a portfolio-weighting problem do you really face?[10] Consider the 2002 Russell Reconstitution. The weights of and companies in the index are reconstituted every July 1. On July 1, 2002, 160 companies were added to the Russell 1000 and 113 were deleted. So at a minimum, 273 of the Russell 1000 companies changed weights from positive to zero and conversely. Another approximately 840 companies had their relative weights change. Is it really the case that holding the market is straightforward? Even an equal-weighted strategy of trying to hold one share of every company misses the mark substantially; pursuing a value-weighted strategy is a task worthy of Sisyphus.

The point being made here is simply that asymmetric information changes the nature of the risk that agents face, and so changes the extent to which idiosyncratic risks can be ignored. In the standard story with an infinite number of assets and an infinite number of agents with the same information, diversification can "work" to remove any asset-specific risk. In particular, if the risks are

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[9] Lest you think this is not possible, note that otherwise, the informed could not hold more of the good assets and less of the bad ones. But then they would all hold the same portfolio—this isn't possible if they have different beliefs, and they do have different beliefs during the trading process or in a partially revealing equilibrium.

[10] The Russell 1000 index measures the performance of the largest 1,000 U.S. companies, representing approximately 92 percent of total market capitalization (see www.russell.com for index details). For a detailed analysis of the Russell Reconstitution, see Madhavan (2002). A similar, albeit smaller problem surrounds the reconstitution of the S&P indexes, and this is examined in Madhavan and Ming (2002).

uncorrelated across assets, then diversifying makes the risk totally vanish. Indeed, with an infinite number of assets, you could simply hold one share of every asset and the story would work. If the risks are correlated, then only market risk remains: The CAPM story. But in either case, the idiosyncratic risk attaching to individual assets is not important.

If there is differential information, however, this is not the case. Everyone thinks that assets are mispriced. The informed buy up the undervalued ones and sell the overvalued. The uninformed have to hold these assets in opposite weights in equilibrium. But if the informed are bearing idiosyncratic risk, so, too, must the uninformed. In effect, it is exactly *because* the uninformed are unable to diversify the risk that the informed are making their profit. And the uninformed know this is happening.

This knowledge is an important distinction between the incomplete information world proposed by Merton (1987) and the asymmetric information world examined here. Traders in Merton's world "don't know what they don't know." Uninformed traders' portfolios in that setting differ from those of informed traders simply because the uninformed are unaware of these other assets. But all traders who know of an asset agree on its expected risk and return. Cross-sectional differences in returns arise in this model because there can be fewer traders in some assets than in others, limiting the risk-sharing ability of the market.[11] It does not reflect the price discovery role that underlies the asymmetric information risk being analyzed here.

Could the actions of the informed traders competing with each other solve the information problem by making the equilibrium revealing? This is essentially saying, Won't we end up back in a symmetric information equilibrium where this problem goes away? But this is just returning to the "as if" becoming "as is." The revealing equilibrium is bizarre from a theoretical perspective; from a microstructure perspective it is nonsense. Markets are complicated; prices are moving and adjusting continuously; and it is the price discovery process that is inherent in the nature of asset pricing.

Microstructure models have extensively analyzed this price discovery process, but typically only in the context of the transactions costs confronting traders.[12]

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[11] There is an extensive literature developing the effects of participation constraints on asset pricing. Here, some traders are precluded from holding particular assets because of exogenous constraints arising from regulation or portfolio management restrictions (see, e.g., Allen and Gale (1994), Brav, Constantinides, and Geczy (2002), and Shapiro (2002)). Such limits on participation can induce differences in return, and may well explain certain market behaviors. But prices here have no informational role, as there is nothing to learn in this setting.

[12] This is not to say that microstructure models have only been concerned with transactions costs (see O'Hara (1995)). An important contribution of this literature was to characterize the price-setting decisions of market intermediaries such as specialists and dealers. These models (see Glosten and Milgrom (1985), Kyle (1985), Easley and O'Hara (1987, 1992), and Holden and Subrahmanyam (1992), to name but a few) showed how the trading mechanism and learning resulted in prices reaching full information values. Thus, unlike the rational expectations models that eschew any aspects of actual market behavior, this literature showed how markets become efficient with respect to new information. However, in all of

The risk aspect of price discovery, and its consonant effect on required returns, has not been part of the microstructure calculus. This absence reflects largely the presumed risk neutrality (or perfect information) of informed traders, the risk neutrality and perfect competitiveness of market makers, and the exogenous trading motivations of the uninformed traders. Thus, price discovery risk only mattered to the extent that it affected the transactions costs of trading.[13] But my argument here is that the effects are broader than this; just as liquidity effects can affect traders' returns, so, too, can price discovery effects affect traders' risks. Both aspects influence utility, and so both liquidity and price discovery should affect asset returns.

So, uninformed traders do learn from prices (having informed traders around is useful) and they also learn from public information. The microstructure of markets matters because it influences the informational content of prices and other market information. Changing a stock's microstructure may thus induce price changes due both to enhanced liquidity and to greater informational efficiency in trading prices.[14] But unless prices are revealing, or public information is perfect, nondiversifiable risk remains. In equilibrium this risk should be compensated. Traders demand extra returns to induce them to hold assets in which information risk is greatest.

III. A Model of Information Risk and Asset Returns

Lest I be accused of loose talk or unscientific thinking, let me now show more formally a simple model of the information effects I have detailed above. The model is a much-simplified variant of the Easley–O'Hara (2001) and Easley, Hvidkjaer, and O'Hara (2002) models, and it involves two risky assets and one bond.[15] One

these models, the "true" value is exogenously given. Thus, the risk aspects discussed in this talk are not a feature of such models. One model in which uninformed traders are allowed greater complexity in their behavior is Spiegel and Subrahmanyam (1992). Here the true value is still exogenous, but uninformed traders are allowed to be risk averse and trade to hedge endowment risk. This analysis shows that many of the standard results regarding price efficiency and liquidity no longer hold.

[13] This liquidity-linkage view is well articulated by Brennan and Subrahmanyam (1996), who note that "a primary cause of illiquidity in financial markets is the adverse selection which arises from the presence of privately informed traders ..." and they add further that "the liquidity effects of asymmetric information are most likely to be captured in the price impact of a trade, or the variable component of trading costs" (p. 441).

[14] The argument here is that particular trading systems may provide more information or better information, allowing the uninformed traders to glean more of the informed traders' private information. But even the staunchest microstructure proponent would shy away from arguing that changing the features of the trading mechanisms could result in such an immediate incorporation of information that prices are in fact revealing, if for no other reason than that changing trading systems also changes traders' strategies.

[15] These models, in turn, can be viewed as multiasset variants of the Grossman–Stiglitz (1980) model (for other variants see Admati (1985) and Wang (1993). One difference between these models and that derived here is that in my model, the random supply shock has a positive mean, implying that assets must be held in equilibrium in positive supply. An alternative approach to modeling asymmetric information is to assume that there are preference

risky asset has only private information, and the other has only public information. I show that the asset with private information requires a higher equilibrium return than does the asset with only public information. I show that the informed and uninformed will hold different portfolios, and that both types of traders willingly hold idiosyncratic risk. I also show that in equilibrium, the uninformed hold more bonds than do the informed traders.

It is also important to note what the model does not include. Missing from the analysis are two features that I think must surely be significant. One is the nature of the information arrival process. For an uninformed trader, it is not just that I am uninformed of new information; I will also not know when new information arrives in the future. The frequency of new information and its dispersion to other traders is surely a dimension of the risk I face in holding the stock. The model also does not include a specific microstructure, using instead the standard price-setting approach of a rational expectations model. These omissions are dictated by tractability, but even with this level of simplification, the model demonstrates a number of important results. These results allow me to discuss in the paper's final section the asset pricing implications of liquidity and price discovery.

A. The Basic Model

Consider a two-period model in which traders choose their portfolios today and the assets in those portfolios pay off tomorrow. There is a bond yielding a gross return R, and there are two risky assets, or stocks. Future values of the stocks are given by $\tilde{v}_i$, where the v_i are independently normally distributed $N(m, 1/\rho)$. The per capita supply of the bond is a fixed amount $\bar{b}$. The per capita supply of the risky stocks, $\tilde{x}_i$, is random, with x_i normally distributed with mean $\bar{x}$ and precision η, or $N(\bar{x}, 1/\eta)$. The presence of a positive expected per capita supply means that on average, in equilibrium some traders will have to hold the asset; this fact, combined with the assets' return being risky, sets the stage for why traders' information will be important. Traders trade today at prices $(1, p_1, p_2)$, where the bond price is normalized to one.

Traders potentially receive a signal, $s_i \sim N(v_i, 1/\gamma)$ about each stock. All traders see signal s_2, and so it corresponds to public information. Signal s_1 is seen by only fraction μ of the traders, and so it corresponds to private information. All signals are received before trade begins. All of these random variables are independent, and all traders know their distributions.

There are J investors (or traders) in the economy, indexed $j = 1, \ldots, J$. These investors all have CARA utility functions with coefficient of risk aversion $\delta > 0$. The investors have an endowment of money that they can use to buy bonds, or one or both of the risky assets.

parameters or beliefs that are not common knowledge. Such an approach can also lead to partially revealing equilibria, and to interesting dynamic asset price behavior (see, e.g., Detemple (2000)).

B. Traders' Portfolio Decisions

Each investor chooses his demands for bond b and for assets (x_1, x_2) to maximize his expected utility subject to a budget constraint. The budget constraint for investor j is $\bar{\psi}^j = b^j + p_1 x_1^j + p_2 x_2^j$, where $\bar{\psi}^j$ is his initial wealth. Investor j's wealth tomorrow, $\tilde{w}^j$, is the random variable $\tilde{w}^j = b^j R + x_1^j \tilde{v}_1 + x_2^j \tilde{v}_2$. Substituting from the budget constraint yields

$$\tilde{w}^j = R\bar{\psi}^j + x_1^j(\tilde{v}_1 - p_1 R) + x_2^j(\tilde{v}_2 - p_2 R). \tag{1}$$

It is straightforward to show that because traders have CARA utility and all distributions are normal, each trader's objective function depends only on means and variances. Solving for investor j's demand for asset i yields

$$x_i^j = \frac{\bar{v}_i^j - Rp_i}{\delta(\rho_i^j)^{-1}}, \tag{2}$$

where $\bar{v}_i^j$ and ρ_i^j are trader j's assessment of the mean future value of stock i and of its precision.

The demand function given in equation (2) depends upon trader j's beliefs regarding the asset's risk and return. For asset 2, all information is public, and so all traders will see the same signal. Using Bayes' rule, it is easy to show that all traders have the same beliefs that are normal, with mean and precision given by

$$\bar{v}_2^j = \bar{v}_2 = \frac{m\rho + s_2\gamma}{\rho + \gamma}, \quad \rho_2^j = \rho_2 = \rho + \gamma. \tag{3}$$

Traders see different information regarding asset 1, and so they do not all have the same beliefs. Some fraction of traders, μ, observes the private signal regarding asset 1's payoffs, but the remaining fraction $(1 - \mu)$ traders do not. Consider first the informed traders. Again, using Bayes rule, it is easy to show that their beliefs are normal with mean and precision:

$$\bar{v}_1^j = \frac{m\rho + s_1\gamma}{\rho + \gamma}, \quad \rho_1^j = \rho + \gamma \tag{4}$$

Determining the beliefs of the uninformed traders regarding asset 1 is more complex. While these traders do not observe the signal, they do know that there is a signal, they know its distribution, and they rationally infer how it will affect the demands of the informed traders and thus the equilibrium price. To learn from the price, these traders must conjecture a form for the price function, and in a rational expectations equilibrium this conjecture must be correct. Suppose the uninformed conjecture the price function

$$p_1 = am + bs_1 - cx_1 + d\bar{x} \tag{5}$$

where a, b, c, and d are coefficients to be determined in the equilibrium.

To compute the beliefs of the uninformed conditional on the price p_1, it is convenient to define the observable random variable Θ to be

$$\Theta = \frac{p_1 - am + \bar{x}(c - d)}{b} = s_1 - \frac{c}{b}(x_1 - \bar{x}) \tag{6}$$

Calculation shows that Θ is distributed as $N(v_1, \rho_\Theta)$, where

$$\rho_\Theta = \left[\gamma^{-1} + \left(\frac{c}{b} \right)^2 \eta^{-1} \right]^{-1}.$$

Thus, given the conjecture in equation (5), the beliefs of the uninformed traders regarding asset 1 are normal, with mean and precision given by

$$\bar{v}_2^j = \frac{m\rho + \rho_\Theta \Theta}{\rho + \rho_\Theta}, \quad \rho_2^j = \rho + \rho_\Theta. \tag{7}$$

C. Equilibrium Asset Returns

In equilibrium, the per capita demand for each asset must equal the per capita supply. For asset 2, determining this equilibrium is straightforward, as substituting all traders' beliefs from equation (3) into the demand function in equation (2) and equating to the per capita supply yields

$$p_2^* = \frac{m\rho + s_2\gamma - \delta\tilde{x}_2}{R\rho_2}. \tag{8}$$

The equilibrium for asset 1 is more complex, as both market clearing and the correctness of the uninformed traders' price conjecture need to be verified. This is essentially the basic problem considered by Grossman and Stiglitz (1980), with some important differences. These differences include multiassets, the positive expected asset supply, and the explicit consideration of differential asset holdings in the REE. This example, even augmented as it is here, is too simple to capture all of the complexities of liquidity and price discovery. A richer model that explicitly includes the microstructure of a specific price-setting mechanism is surely the goal. But even in this simple model, the effects of information on required returns can be illustrated. The proposition characterizes the nature of this equilibrium.

PROPOSITION 1: *There exists a partially revealing equilibrium for asset 1 in which*

$$p_1 = am + bs_1 - cx_1 + d\bar{x}$$

where

$$a = \rho/z, \quad b = \frac{(\mu\gamma + (1 - \mu)\rho_\Theta)}{z}, \quad c = \frac{\delta\left[1 + \frac{(1-\mu)\rho_\Theta}{\mu\gamma} \right]}{z},$$

$$d = \frac{\frac{\delta(1-\mu)\rho_\Theta}{\mu\gamma}}{z}, \rho_\Theta = \left[\gamma^{-1} + \left(\frac{\delta}{\mu\gamma} \right)^2 \eta^{-1} \right]^{-1}, \quad z = R(\rho + \mu\gamma + (1 - \mu)\rho_\Theta).$$

Proof: See the Appendix.

The equilibrium depicted above is partially revealing in the sense defined by Grossman and Stiglitz (1980). The uninformed cannot learn the informed traders' information from the price, but they can draw inferences from the price about the information. These inferences will be correct, but not complete; thus, the uninformed will learn from the price, but they will still be at a disadvantage relative to the informed traders. Recall, however, that the uninformed also influence the price through their demands. Thus, equilibrium prices reflect a confluence of factors relating to information, risk, and asset fundamentals. I now turn to establishing some specific properties of this equilibrium. The next proposition examines the risk premium for each asset and shows that it is higher for the asset with private information.[16]

PROPOSITION 2:   *In equilibrium, there is a positive risk premium $E[v_i - Rp_i{}^*]$ for each risky asset. Further, $E[v_1 - Rp_1^*] > E[v_2 - Rp_2^*]$.*

Proof: See the Appendix.

Proposition 2 shows that in equilibrium both assets 1 and 2 command a risk premium. This premium reflects the fact that these assets are risky, and traders demand compensation to hold them in equilibrium. What is perhaps more significant for our discussion is that these risk premia are not the same across the two risky assets: Traders demand higher compensation to hold the asset with private information. This differential return arises not from any differences per se in the underlying asset. Rather it compensates traders for the "information risk" they face in trading with traders who have superior information. Indeed, the difference in excess returns is given by

$$E\left[v_1 - Rp_1^*\right] - E\left[v_2 - Rp_2^*\right] = \bar{x}\delta \frac{(1-\mu)(\gamma - \rho_\Theta)}{(\rho + \gamma)(\rho + \mu\gamma + (1-\mu)\rho_\Theta)} > 0 \qquad (9)$$

This difference is zero only if there are no uninformed traders ($\mu = 1$), or if prices are perfectly revealing ($\rho_\Theta = \gamma$). Otherwise, this return is positive and it is increasing to the extent to which information is private. This is a variant of the information risk that David Easley and I showed in Easley et al. (2002) and Easley and O'Hara (2001).

The price effects of information detailed above are not the price effects typically focused on in standard microstructure models. In microstructure models, the presence of informed traders causes a spread to arise between the price to buy the asset and the price to sell the asset. This spread reflects the intertemporal mechanics of price discovery when orders are not all synchronous, and it compensates the market maker for the losses incurred by trading with better-informed agents. In effect, it reflects the break-even amount that a risk-neutral market maker needs to provide liquidity to buyers and sellers in such a market. It

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[16] The expectations in Proposition 2 are ex ante expectations. Note that this analysis controls for total information. So the interpretation is that it is showing higher returns for the asset with a greater proportion of information being private than public.

is not compensation for the risks of price discovery, per se, because the market maker is risk neutral. The uninformed are also not being compensated for this risk, because they are assumed to be willing to trade at the price the market maker sets. Thus, microstructure models include the liquidity and mechanics of price discovery features of markets, but not the risks of price discovery and its effects on the price process.

In the model considered here, there is no spread; all trade takes place at a single price reflecting the intersection of the supply and demand curves in the economy. Liquidity issues do not arise, per se, because all trading takes place synchronously.[17] Instead, the price effect arises because uninformed traders need compensation to hold the asset. In effect, it is the risk of discovery aspect that is being priced. Adding liquidity problems or including the mechanics of price discovery would increase the transactions costs of trading, but would not diminish the price effects found here.

Let us now consider how traders' portfolios differ in this asymmetric information world. It is easy to show that all traders have the same demand for asset 2, the asset in which signals are public. This follows because all traders have the same beliefs regarding the asset's risk and return, and so solving equation (4) with these beliefs results in identical demands. This is not the case with asset 1. Let x_1^I and x_1^U denote the typical holdings of asset 1 by the informed and uninformed agents, respectively. The question of interest is how do these demands differ between the informed and uninformed traders? Looking at the expected difference produces

$$E\left[x_1^I - x_1^U\right] = \frac{\bar{x}(\gamma - \rho_\Theta)}{(\rho + \mu\gamma + (1-\mu))\rho_\Theta} > 0. \tag{10}$$

So, on average, the informed traders hold more per capita of the stock with private information than the uninformed traders do. Notice that this result is on an ex ante basis. Depending upon the value of the private information signal, the informed traders will ex post demand more of the stock when there is good news and less when there is bad news. But on average, the informed investors demand more of the stock, reflecting the lower risk that arises from their superior information.

The uninformed, conversely, hold more bonds. This follows because the informed and uninformed have the same initial wealth and the same demand for the stock with public information. But from above, the uninformed hold less of the private information stock, and so they complete their portfolio allocation by holding bonds.

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[17] There are trading mechanisms in which assets clear at a single price. Investment Technology Group (ITG)'s POSIT system, for example, matches buy and sell orders and clears all trades at the prevailing price on the NYSE or Nasdaq. Such a mechanism allows buyers and sellers to minimize the price impacts of their trades while accepting the possibility of execution risk. This differs from the equilibrium considered here, in that POSIT orders do not contribute to price discovery. Call markets, in general, feature trading at a single price, and may also include price discovery, as in the NYSE open.

These results highlight an important feature of the asymmetric information equilibrium: There is no single market portfolio being held. Informed traders hold one portfolio of assets; uninformed traders hold another. This difference arises not because agents are unaware of the assets in the economy, but rather because they differ in the quantities they want to hold, given their beliefs about the asset's expected risk and return. The informed traders willingly bear idiosyncratic risk because they perceive some assets to be mispriced. They weight their portfolios more heavily towards those assets they believe to be undervalued and they hold less of the assets they perceive to be overvalued. The uninformed also find assets to be mispriced given their information; in equilibrium, they will end up holding what the informed don't want, so their portfolios will also bear idiosyncratic risk.[18]

There are two features of this uninformed equilibrium demand that I want to emphasize. First, recall that the uninformed can avoid this risk entirely by simply holding bonds and asset 2, but they choose not to do so. Indeed, the uninformed demand for asset 1 is only zero if there is no risk premium (an outcome ruled out on average by Proposition 1) or if ρ^U is zero. But $\rho^U = \rho + \rho_\Theta$, so this term is zero only if the prior precision is zero and the uninformed are stupid, that is, they learn nothing from prices. Since this is not the case, the uninformed willingly bear idiosyncratic risk.

Second, the uninformed also do not simply hold some fixed quantity of the risky asset. Since the uninformed do not have state-contingent information, one might suppose that a strategy of holding some average amount would be optimal. To see why this is incorrect, let us conjecture that the uninformed chose to hold $\bar{x}$, or the mean of the expected asset 1 supply. If a single uninformed trader does this, then prices are not affected. Since $\bar{x}$ does not maximize her expected utility, this clearly makes her worse off. Such an outcome should not be unexpected; the uninformed are neither stupid nor naïve. Holding a fixed amount of the risky asset essentially requires the uninformed to ignore the information they glean from the price. The uninformed can do better than that, and so their demands in equilibrium for asset 1 differ across states of the world.[19]

What then do we conclude from this simple model of asset pricing with asymmetric information? First, both informed and uninformed traders willingly hold idiosyncratic risk. Second, informed and uninformed traders hold the same assets, but not the same portfolios. This composition difference results in uninformed traders' equity holdings containing more of the bad news stocks and less of the good news ones. Third, in equilibrium, uninformed asset holdings differ across stocks, depending upon the information traders glean from market

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[18] This effect reflects what Grossman (1994) termed "incomplete equitization," in that the uninformed cannot avoid the risk that arises from information in equilibrium.

[19] Indeed, the uninformed are worse off if they hold any fixed quantity of asset 1, and not just if they hold $\bar{x}_1$. Returning to our earlier example of holding the Russell funds, this finding suggests why holding shares in an equally weighted index fund is dominated by holding shares in a value-weighted fund. In the latter, uninformed traders are at least varying the quantity they hold, depending upon the market price.

statistics. Having established the equilibrium effects of asymmetric information, I now turn in the final section to discussing some implications for asset pricing.

IV. Information and Asset Pricing

The intuition developed in this address is straightforward: Assets trade in markets, markets provide liquidity and price discovery, and asset prices are influenced by the transactions costs of liquidity and the risks of price discovery. In this final section, I argue that this framework is useful for understanding a variety of issues connected with asset prices. Brevity requires selectivity, so I touch on two specific applications and one more general observation. I first discuss the basic issue of asset returns and what my analysis implies for the cross-sectional properties of asset prices. I then focus on the equity premium puzzle, and I discuss how price discovery provides at least a partial explanation for this conundrum. Lastly, I consider how the analysis here relates to the fundamental concept of market efficiency.

A. Cross-sectional Asset Returns

The model in the previous section shows that the equilibrium risk premium is higher for assets in which a larger fraction of the information is private rather than public. This result, initially developed in Easley et al. (2002; hereafter EHOH) and Easley and O'Hara (2001), suggests a complexity to asset returns not captured by symmetric information models. In particular, a firm's information structure will affect its equilibrium return, with traders demanding compensation to hold stocks in which the risk of information-based trading is higher. EHOH (2002) provide empirical support for this proposition by showing that PIN, a measure of informed trading, is priced in asset returns. The PIN measure is derived from a market microstructure model in which a stock's pattern of trading volume and trade imbalances is linked to the frequency and dispersion of information risk. Estimating this variable on a stock-by-stock basis annually for a 15-year period, EHOH find that a 10 percent increase in a stock's PIN leads to a 2.5 percent increase in its required return, an amount both economically and statistically significant. The PIN measure is admittedly crude, but it does capture important features of the information environment, such as the expected frequency of information events, the dispersion of information across traders, and the rates of informed (and uninformed) trading. I believe that better measures can be developed, leading to a greater ability to delineate the influence of information risk on asset prices.

That information risk can affect asset returns is a departure from the standard view that only market risk is priced. Yet, increasingly asset pricing models have recognized the role played by factors other than β. Thus, asset pricing models including book-to-market factors, or size factors, or momentum factors can also be viewed as departing from this standard paradigm. What is more significant here is that information risk provides an explanation for why idiosyncratic risks matter for asset pricing. Campbell et al. (2001) find that while market volatility

has remained relatively constant over the period from 1926 to 1998, individual firm or idiosyncratic risk has increased substantially over this period, to the point that it is now the largest component of a firm's total volatility.[20] Goyal and Santa-Clara (2003), in a paper presented at these meetings, argue that average stock variance (which is largely idiosyncratic) matters for asset pricing. Thus, the notion that idiosyncratic risk is irrelevant for asset pricing is increasingly coming into question. If, as I have argued here, the price discovery role matters in asset pricing, then such findings should not be unexpected.

Incorporating this price discovery role also explains why diverse factors, such as the microstructure of where a stock trades, or the firm's accounting treatment of earnings and other operating information, or the legal structure where a firm operates, or even the number of analysts following a stock, will affect the return investors want in equilibrium. And it also provides an explanation for why the disclosure policy a firm adopts is not irrelevant for its valuation. Corporate finance research has long argued that the information structure of a firm is relevant for its cost of capital. Such a result is inconsistent with the traditional symmetric information asset pricing models in which firm-specific features are not relevant, but it will surely matter if information risk affects asset pricing.

There is also an increasing number of papers developing the notion that liquidity can affect asset pricing. Thus, authors have argued that asset returns are influenced by spreads, volume, liquidity ratios (the daily price change divided by volume), lagged liquidity ratios (the same variables lagged a day), turnover, and even the volatility of turnover. As noted before, I find the argument that liquidity costs, if high enough, can affect asset prices to be quite credible. Whether these liquidity costs differ across stocks in a way to induce cross-sectional return effects is less clear, but it may be that these costs induce interesting time-series effects (see Amihud (2002) for discussion). I suspect that some of these variables may actually be capturing more the risks of price discovery than the transactions costs of liquidity. Since these two functions are typically present at the same time, it is not surprising that these effects appear congruent. More research to differentiate these influences would seem particularly promising.

B. The Equity Premium and Related Puzzles

A perennial puzzle in asset pricing is the seemingly excessive premium that stocks command over bonds. This premium appears inconsistent with the level of risk inherent in stocks, and while a number of explanations have been posed, none has proved definitive. One explanation suggested by this analysis is that information risk may be part of the answer. Specifically, when there is asymmetric information, uninformed traders lose out to informed traders when they hold equities. As shown in the last section, the uninformed traders respond to this risk by demanding greater asset-specific compensation and by holding more bonds in equilibrium. This portfolio allocation reflects that equities, in general,

[20] These authors suggest a number of possible explanations for this effect but conclude "any such explanations can only be tentative" (p. 33).

are risky to the uninformed trader, and so they avoid holding as many. It seems quite believable that such portfolio decisions will also affect equilibrium returns, with the result that equities, in general, require higher returns than would seem sensible by a symmetric information metric.[21]

That information risk could affect the overall level of prices, and not just those of specific assets, may also explain regularities such as home bias. This pricing anomaly refers to the lower returns that domestic assets command relative to foreign assets, or to the related finding that local companies tend to be more highly valued by local investors (see Coval and Moskowitz (1999) or Huberman (2001)). To the extent that uninformed investors have better priors, or greater access to public news for local than foreign assets, then such assets will pose a lower informational disadvantage for the uninformed. In equilibrium, a lower risk premium is required (see Brennan and Cao (1997) for an analysis of such effects).

C. Price Discovery and Market Efficiency

The premise developed in this talk is that liquidity and price discovery are important dimensions of asset markets and, by extension, of asset prices. That information should affect asset prices is hardly news; finance researchers have long focused on the informational efficiency of asset prices. The innovation here is the argument that when information is asymmetric, uninformed investors demand compensation for portfolio-induced risks which they cannot diversify.

Note that my arguments do not imply that markets are necessarily inefficient; there are no arbitrage opportunities here, nor is there the proverbial free lunch. Traders with superior information will move prices toward full information levels, but continuously attaining full information levels is not credible—new information arrives, old information becomes stale, and even informed traders may face risks that their information is obsolete. Market prices can be martingales with respect to information, but if traders have diverse information sets, then these expectations need not be the same across traders. Thus, as in microstructure models, the adjustment of prices to full information values can differ widely across markets that are deemed efficient. And it is this difference in adjustment that gives rise to the effects discussed here.

Appendix

Proof of Proposition 1:   It is sufficient to show that there is an equilibrium price of the form given in the statement of the proposition. Equating mean per capita demand by informed and uninformed traders to per capita supply gives

$$\mu \left[\frac{\rho m + \gamma s_1 - R p_1 (\rho + \gamma)}{\delta} \right]$$
$$+ (1 - \mu) \left[\frac{\rho m + \rho_\Theta \Theta - R p_1 (\rho - \rho_\Theta)}{\delta} \right] = x_1. \tag{A1}$$

[21] See Zhou (1999) for an alternative information-based explanation.

So,

$$p_1 = \frac{\rho m + s_1(\mu\gamma + (1-\mu)\rho_\Theta) - x_1\left(\delta + (1-\mu)\rho_\Theta\left(\frac{c}{b}\right)\right) + \bar{x}(1-\mu)\rho_\Theta\left(\frac{c}{b}\right)}{R\rho + \mu R\gamma + (1-\mu)R\rho_\Theta} \quad (A2)$$

The ratio of the coefficients on s_1 and $-x_1$ in equation (A2) must be (c/b). Solving gives

$$\frac{c}{b} = \frac{\delta}{\mu\gamma}$$

So

$$\rho_\Theta = \left[\gamma^{-1} + \left(\frac{\delta}{\mu\gamma}\right)^2 n^{-1}\right]^{-1}$$

Note that the coefficients in equation (A2) are as given in the statement of Proposition 1. Q.E.D.

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

$$E\left[v_2 - Rp_2^*\right] = \frac{\delta\bar{x}}{\rho + \gamma} \quad (A3)$$

The expected return on stock 1 is by Proposition 1,

$$E\left[v_1 - Rp_1^*\right] = \frac{\delta\bar{x}}{\rho + \mu\gamma + (1-\mu)\rho_\Theta}$$

Note from Proposition 1 that $\rho_\Theta < \gamma$, so $E[v_1 - Rp_1^*] > E[v^2 - Rp_2^*]$. Q.E.D.

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