Information Asymmetry, Information Precision, and the Cost of Capital

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Abstract

This paper examines the relation between information differences across investors (i.e., information asymmetry) and the cost of capital, and establishes that with perfect competition information asymmetry makes no difference. Instead, a firm's cost of capital is governed solely by the average precision of investors' information. With imperfect competition, however, information asymmetry affects the cost of capital even after controlling for investors’ average precision. In other words, the capital market’s degree of competition plays a critical role for the relation between information asymmetry and the cost of capital. This point is important to empirical research in finance and accounting.

JEL classification:   G12, G14, G31, M41

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1 Introduction

This paper analyzes the role of information asymmetry in the determination of a firm’s cost of capital. Information asymmetry among investors has been a long-standing concern to securities regulators (e.g., Loss, 1983; Loss and Seligman, 2001). For example, the Securities and Exchange Commission (SEC) recently enacted Regulation Fair Disclosure (Reg FD), which prevents companies from making disclosures to select groups of investors and analysts. The SEC (2000) argued that selective disclosure creates information asymmetry, which could lead to investors demanding a larger risk premium and hence raise firms’ cost of capital (see also Levitt, 1998). In contrast, critics argued that the Reg FD could stifle corporate disclosure and hence that the proposed regulation would increase firms’ cost of capital (AIMR, 2001). For example, SEC Commissioner Unger (2000) voted against the proposed regulation because of concerns that it would “most likely reduce the amount of information available to investors.” As this example illustrates, the consequences of information asymmetry in capital markets, in particular, for firms’ cost of capital are of central importance to securities regulators but still much debated.

In the academic literature, there is also considerable debate as to how or when information asymmetry manifests in the cost of capital, and many studies have reached different conclusions. Information differences across investors are critical features of noisy rational expectations models and models of market microstructure. For example, Admati (1985) shows that the average precision of investors’ private information is relevant for determining the cost of capital. Leland (1992) finds that allowing insider trading, on average, increases stock prices despite the fact that the presence of insiders increases information asymmetry
in the economy. Although he does not couch his analysis in terms of cost of capital, a higher stock price is tantamount to a decrease in a firm’s cost of capital. In contrast, O’Hara (2003), Easley and O’Hara (2004) and Hughes, Liu, and Liu (2007) conclude that information asymmetry increases firms’ cost of capital. Specifically, Easley and O’Hara (2004) analyzes differences in the composition of information between public and private information. They argue that less informed traders recognize they are at an information disadvantage, and hold fewer assets as a consequence. This in turn drives down the price of securities with high degrees of private information and hence information asymmetry, thereby increasing the cost of capital for these firms. They conclude that private information thus induces a new form of systematic risk, and in equilibrium investors require compensation for it. In contrast, Wang (1993) finds that increasing the percentage of informed investors in the economy lowers the cost of capital. Wang notes that his results are attributable to the joint effect of both information asymmetry and average precision.

Our paper contributes to this debate by clarifying the role of information asymmetry in the determination of a firm’s cost of capital. To illustrate our central research question and convey the main message of our paper, consider two otherwise identical market settings where shares of a firm are traded. In one setting investors have homogeneous beliefs about the firm’s prospects; as such, investors have a homogeneous level of information. For convenience, we refer to this level of information as $\Pi$ (we will be more precise in defining these concepts in Section 2). In the other setting, one set of investors is better informed about the firm’s prospects than another set of investors. Again for convenience, we refer to the level of information of the better informed investors as $\Pi_I$ and the level of information of the less informed investors as $\Pi_U$, where $\Pi_I$ exceeds $\Pi_U$ (as measures of the level of information).
Finally, assume that the average level of information about the firm is identical in the two settings: in other words, when the levels of information of the better informed investors ($\Pi_I$) and the less informed investors ($\Pi_U$) are averaged across the two investor types, the average in this setting is also $\Pi$. The question is now: In which setting is a firm’s cost of capital higher, considering that the average level of information is the same in both settings but that the distribution of information (i.e., the level of information asymmetry) differs?

The answer we provide to this question is: If the market in firm shares is perfectly competitive, then the cost of capital will be identical in both settings. In a perfect competition setting, it makes no difference whether some investors have more information than others; a firm’s cost of capital is governed solely by the average precision of investors’ information. With imperfect competition, however, information asymmetry has an effect on the cost of capital even after controlling for the effect of average precision of investor information. In other words, the degree of competition in the capital market plays a critical role for the relation between information asymmetry and the cost of capital.

To describe our analysis and results in more detail, we consider a model of trade that derives from Kyle (1989); in this model large investors can have an impact on price, and thus take this effect into account in determining their demands. In our model, the degree to which competition is imperfect (i.e., markets are illiquid) is an endogenous feature, and influences the effect of information asymmetry on the cost of capital. In particular, the degree of market illiquidity affects the aggressiveness with which informed investors base their trades on price, which in turn determines the informativeness of price, and therefore the precision of the information that less informed investors glean from price. Moreover, we show that the degree of illiquidity also affects the relative weight that the precision of informed investors’
information receives in determining price. In other words, an important determinant in the
cost of capital is the interaction between imperfect competition and information asymmetry.

The model also allows us to consider the case when markets are perfectly competitive.
We show that when the capital market is characterized by perfect competition and investors
act as price-takers, as is the case in the Capital Asset Pricing Model (CAPM) and most
noisy rational expectations models, information asymmetry can affect the cost of capital
only through its effect on the average precision of investors’ information. In this setting,
increasing the quality of publicly available information can reduce information asymmetry
between investors and also reduce the cost of capital. But this effect on cost of capital occurs
solely because increasing the quality of public information increases the average precision of
investors’ information, not because it reduces information asymmetry, per se. We show that
decreasing information asymmetry can cause the average precision of investors’ information
to either increase or decrease. When the latter happens, the cost of capital increases.

Our result that the degree of competition is critical in understanding the role of informa-
tion asymmetry dovetails nicely with the literature on market microstructure: for example,
seminal papers such as Kyle (1985), Glosten and Milgrom (1985), and Amihud and Mendel-
son (1989). Imperfect competition is a salient feature of these papers, and the role that
informationally advantaged investors have on the equilibrium bid-ask spread and path of
prices is well studied. But much of the imperfect competition literature is characterized
by the assumption that market agents are risk neutral. For example, risk neutrality is a
standard assumption in papers such as Admati and Pfleiderer (1988), Fishman and Hagerty
(1992), and Bernhardt and Taube (2008). When market agents are risk neutral, all invest-
ments earn the risk-free rate; there is no notion of investors discounting a firm’s cash flow
for risk. Because investors do not price risk, there is no notion of cost of capital as in the CAPM, say. In contrast, our paper assumes that investors are risk averse and thus discount for risk. This allows us to integrate imperfect competition into a notion of cost of capital.

An important implication of our analysis is that, in perfect competition settings, there is no separate, systematic risk factor in price that stems from private information or information asymmetry, as for instance claimed in Easley and O’Hara (2004). In perfect competition settings less informed investors choose to hold fewer shares in firms where their uncertainty is greatest, not where information asymmetry is greatest. In fact, an investor’s degree of uncertainty decreases when other investors acquire more information (even when it is private), because this information gets communicated (partially) through price when investors condition their expectations over price in determining their demand (e.g., Grossman and Stiglitz, 1980; Leland, 1992). In other words, increasing information asymmetry when markets are perfectly liquid can actually decrease a firm’s cost of capital, as long as the change in information structure increases investors’ average precision.

Aside from its theoretical contributions, our paper also has several empirical implications. First, a growing literature in finance and accounting empirically examines the relation between various information attributes and the cost of capital. Many of these studies implicitly or explicitly treat the information attribute (e.g., information asymmetry, the probability of informed trade, disclosure or earnings quality) as a separate (information) risk factor: that is, they introduce the variable separately into a cost of capital regression next to beta and

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1 See Easley, Hvidkjaer, and O’Hara (2002; 2010); Botosan and Plumlee (2003), Botosan, Plumlee, and Xie (2004); Francis, LaFond, Olsson, and Schipper (2005); Barth, Konchitchki, and Landsman (2006); Nichols (2006); Chen, Shevlin, and Young (2007); Kravet and Shevlin (2007); Duarte, Han, Harford, and Young (2008); Core, Guay and Verdi (2008); and Ogneva (2008).
other known risk factors. Our analysis shows that such an empirical specification cannot be supported by models of perfect competition. In these models, a separate information risk factor that is attributable to information asymmetry does not affect cost of capital.

Second, we show that it is important to distinguish between information asymmetry and information precision. While many empirical studies on the role of information for the cost of capital view their results as related to the degree of information asymmetry in the market, it is important to note that information asymmetry proxies are often highly related to the average precision of investors’ information as well. Absent an attempt to untangle these two economic constructs, researchers may misattribute empirical results to one construct versus the other. Underscoring our point, Bhattacharya, Ecker, Olsson and Schipper (2009) use path analysis to decompose the association between earnings quality and the cost of capital and provide evidence that suggests both a direct path to the cost of capital, consistent with a precision effect, and an indirect path mediated by information asymmetry.

Third, our analysis provides the testable prediction that information asymmetry plays a larger role in cost of capital if firms’ shares trade in markets that are characterized by imperfect competition. Armstrong, Core, Taylor and Verrecchia (2011) explores this idea empirically and finds that information asymmetry has a positive relation with firms’ cost of capital in excess of standard risk factors when markets are imperfect, and no relation when markets approximate perfect competition. Thus, consistent with our theoretical prediction, Armstrong et al. (2011) shows that the degree of market competition is an important conditioning variable when examining the relation between information asymmetry and cost of capital (see also Akins, Ng, and Verdi, 2011). Our prediction also has implications for policy analysis. For instance, our prediction suggests that the concern about selective disclosure
that gave rise to Reg FD is less relevant to firms that are heavily followed by analysts and very actively traded. For these firms, the effect of Reg FD on the cost of capital is governed primarily by the regulation’s effect on the average precision of investor information. In contrast, for smaller, less followed stocks, the effect of Reg FD on information asymmetry could indeed affect firms’ cost of capital, over and above any effects on the average level of information in the economy.

In Section 2 we describe an economy that incorporates both information asymmetry and imperfect competition, and derive conditions for a unique equilibrium. In Section 3 we apply the results of our analysis to study the cost of capital. In a concluding section we summarize our results.

2 Capital Market Setting

In this section we formulate a one-period capital market that consists of a single risky asset and a riskless asset. We normalize the return on the risk-free asset to 1. Let \( \tilde{V} \) denote the risky asset’s cash flow and \( \tilde{V} = V \) the realization of its end-of-period cash flow.\(^2\) Let \( E[\tilde{V}] \) denote the a priori expected value of the risky asset’s cash flow, and \( \sigma_v^2 \) and \( \Pi_v \) the a priori variance and precision of the risky asset’s cash flow, respectively. Let \( \tilde{P} \) denote the risky asset’s price and \( \tilde{P} = P \) the realization of the end-of-period price. We summarize the notation we employ in Table 1. [Insert Table I here.]

Two key features of the economy in our model are that market participants are asymmetrically informed and that the market is imperfectly competitive. Information asymmetry results whenever some subset of investors does not have access to the private information

\(^2\) Henceforth we use a tilde (i.e., “~”) to distinguish a random variable from a realization or fixed element.
that is available to other investors. Information asymmetry is a common feature of noisy rational expectations (RE) models (e.g., Grossman and Stiglitz, 1980; Easley and O’Hara, 2004). In the vast majority of noisy RE-models, as well as homogeneous information models such as the CAPM, investors are assumed to be price-takers: that is, investors face perfect competition. In contrast, in our model informed investors must take into account the effect that their trades have on prices. Similar to Kyle (1989), the degree of imperfect competition is an endogenous feature of the model. Perfect competition is a special case of our more general analysis.

Specifically, we posit an economy composed of two types of investors: \( N \) identically informed investors and a large number of very small (i.e., atomless) uninformed investors. To distinguish between the two types of investors, we subscript parameters and activities associated with informed and uninformed investors by \( I \) and \( U \), respectively. We assume that each investor has a negative exponential utility function with constant absolute risk tolerance \( r_t \), where \( t \) distinguishes an investor’s type, i.e., \( t \in \{I, U\} \). Let \( \Phi_t, t \in \{I, U\} \), represent the information available to an investor of type \( t \). Henceforth let \( \Pi_t \) denote the posterior precision an investor of type \( t \) associates with the risky asset’s cash flow.

Each informed investor observes the same private information signal, \( \tilde{X} = \tilde{V} + \tilde{\varepsilon} \), where \( \tilde{\varepsilon} \) is an “error term” whose expected value is 0 and whose variance and precision are \( \sigma_{\varepsilon}^2 \) and \( \Pi_{\varepsilon} \), respectively. In addition, each informed type observes price; price does not convey, however, any incremental information to informed investors because they are all identically informed.

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4 For example, the only other paper that we are aware of that studies cost of capital in an imperfect competition setting is Diamond and Verrecchia (1991).
When an informed investor observes $\tilde{X} = \tilde{V} + \tilde{\varepsilon}$, the precision of his beliefs about the risky asset’s cash flow is $\Pi_I = \Pi_v + \Pi_\varepsilon$. Moreover, a straightforward application of Bayes’ Theorem implies that the expected value an informed investor assigns cash flow based on his private information is

$$E \left[ \tilde{V} | \Phi_I \right] = E \left[ \tilde{V} \right] + \frac{\Pi_\varepsilon}{\Pi_I} (X - E \left[ \tilde{V} \right]),$$

(1)

where the information set of the informed investors is $\Phi_I = \{ \tilde{P} = P, \tilde{X} = X \}$.

We capture information asymmetry by introducing into our economy a class of investors who do not have access to the private information available to informed investors: we refer to this investor-type as “uninformed investors.” Nonetheless, as is standard in any RE-setting, uninformed investors glean some of the informed investors’ private information about the risky asset’s cash flow by conditioning their expectations on price.\(^5\) With this in mind, let $\Phi_U = \{ \tilde{P} = P \}$ represent the information available to uninformed investors.\(^6\) We express the precision of uninformed investors’ posterior beliefs about the risky asset’s cash flow as $\Pi_U = \Pi_v + \Pi_\delta$, where $\Pi_\delta$ is the precision of the information that uninformed investors glean from price. Because one investor-type possesses strictly more information than the other, in terms of their private information alone we measure the degree of information asymmetry between the two types by $\Pi_\epsilon$, and in terms of their equilibrium (or posterior) precisions we measure information asymmetry by $\Pi_I - \Pi_U = \Pi_\varepsilon - \Pi_\delta$. Note that $\Pi_\delta$ is endogenous; we derive it below.

\(^5\) See, for example, Grossman and Stiglitz (1980), Hellwig (1980), and Diamond and Verrecchia (1981).

\(^6\) It is straightforward to incorporate into the analysis public information signals, i.e., signals that are observed by both types of investors. In this circumstance the posterior precision of each investor type increases by the precision of the error term of the public signal.
2.1 An Informed Investor’s Demand

Imperfect competition settings are inherently complex. Thus, we break up the analysis into a series of steps that ultimately establish conditions for the existence of an equilibrium to the economy we describe. We begin by determining an informed investor’s demand for shares in the risky asset. Let \( D_I \) represent an informed investor’s demand for shares in the risky asset. Informed investors are finite in number, and thus following Kyle (1989) we assume that each informed investor has a self-sustaining belief that he faces an upwardly-sloping price curve for shares in the risky asset. In particular, we assume each investor believes that his demand is related to the price through the expression

\[
P = p_0 + \lambda \cdot D_I, \tag{2}
\]

where \( p_0 \) is an intercept term that incorporates all elements of price that are not related to an investor’s demand, and \( \lambda \) is a non-negative coefficient. In effect, each investor believes that price results from a factor that is unrelated to his demand, \( p_0 \), and a factor that is related to his demand through the coefficient \( \lambda \). Our goal is to solve for \( P, p_0, \lambda, \) and \( D_I \), all of which are endogenous variables that must be derived to achieve an expression for the cost of capital. As is standard in a model of imperfect competition, we interpret \( \lambda \) as the degree of illiquidity associated with an individual investor’s demand. For example, when \( \lambda \) is small, an investor’s demand moves price less, and thus the market for an asset’s shares is more liquid with respect to demand; when \( \lambda \) is large, an investor’s demand moves price more, and thus the market is less liquid for shares in the risky asset. Henceforth, for convenience we refer to \( \lambda \) as an individual informed investor’s coefficient of illiquidity.

We assume that each informed investor has a negative exponential utility function for an
amount \( w \) given by \(- \exp \left( -\frac{w}{r_I} \right)\), where \( r_I \) is an informed investor’s constant absolute risk tolerance. When investors have negative exponential utility functions and the risky asset has a normal distribution, the certainty equivalent of each investor’s expected utility simplifies into the familiar expression of the expected value of his end-of-period wealth minus a term that is proportional to the variance of his wealth. Let \( \Phi_I \) represent the information available to each identically informed investor. We assume that each investor believes that the risky asset yields a cash flow of \( \tilde{V} \) at the end of the period, where \( \tilde{V} \) has a normal distribution with an expected value of \( E \left[ \tilde{V} | \Phi_I \right] \) and precision \( \Pi_I \). Thus, based on his belief as to how his demand affects prices, an informed investor chooses \( D_I \) to maximize the following objective function

\[
\left( E \left[ \tilde{V} | \Phi_I \right] - (p_0 + \lambda D_I) \right) D_I - \frac{1}{2r_I \Pi_I} D_I^2.
\]

(3)

Taking the derivative with respect to \( D_I \) and re-arranging terms yields

\[
D_I = \frac{E \left[ \tilde{V} | \Phi_I \right] - (p_0 + \lambda D_I)}{\frac{1}{r_I \Pi_I} + \lambda}
\]

\[
= \frac{E \left[ \tilde{V} | \Phi_I \right] - P}{\frac{1}{r_I \Pi_I} + \lambda},
\]

(4)

where the last equality follows from the relation \( P = p_0 + \lambda D_I \). Note that Equation (4) reduces to the standard expression for demand for asset shares in a perfect competition setting when \( \lambda \) is 0.\(^7\) If \( \lambda \) is not 0, then higher \( \lambda \) lowers an investor’s demand for shares (ceteris paribus). Intuitively, this is because the more an investor demands, the higher the price he pays, not just for the next share, but for all the shares he demands of that asset.

For example, let \( \beta \) denote the sensitivity of an informed investor’s demand as a function of

\(^7\) See, for example, eqns. (8) and (8') of Grossman and Stiglitz (1980).
his (private) information. Then $\beta$ is defined as

$$\beta = \frac{\partial}{\partial X} D_I = \frac{P_I}{r_I \Pi_I + \lambda},$$

(5)

and decreases as $\lambda$ increases. In other words, the more illiquid the market, the less aggressively informed investors condition their demands on their private information.

### 2.2 An Uninformed Investor’s Demand

We assume that each uninformed investor has a negative exponential utility function for an amount $w$ given by $-\exp\left(-\frac{w}{r_U}\right)$, where $r_U$ is an uninformed investor’s constant absolute risk tolerance. Uninformed investors in our model represent an investor class that is made up of a very large number of very small investors. Because they are large in number but individually carry little weight in trade in shares in an asset, uniformed investors behave as price takers.\(^8\) Price-taking behavior implies that each uninformed investor believes that his demand has no effect on prices, and in equilibrium this belief is sustained. Let $D_U$ represent an uninformed investor’s demand for shares in the risky asset. Based on his belief that his demand has no effect on price, an uninformed investor takes price as a given and chooses $D_U$ to maximize the following objective function:

$$\left( E\left[\tilde{V} \mid \Phi_U \right] - P \right) D_U - \frac{1}{2r_U \Pi_U} D_U^2,$$

(6)

where $\sigma_U^2$ represents an uninformed investor’s beliefs about the variance of risky asset’s cash flow. Solving for $D_U$ yields

$$D_U = r_U \Pi_U \left( E\left[\tilde{V} \mid \Phi_U \right] - P \right).$$

(7)

\(^8\) In principle, we could also allow the uninformed investors to face imperfect competition. An analysis along these lines is considerably more cumbersome, however, because here each investor-type faces a different illiquidity coefficient (i.e., $\lambda_I$ versus $\lambda_U$). All of the qualitative insights discussed in the paper carry over to this setting.
2.3 Market Clearing

Market clearing requires that the total demand for an asset’s shares equals the supply of those shares. Let \( \tilde{Z} \) represent the (random) supply of shares in the risky asset. As is standard in noisy rational expectations models, we require \( \tilde{Z} \) to be random in order to prevent uninformed investors from inverting price to infer perfectly the informed investors’ information. We assume that \( \tilde{Z} \) has a normal distribution that is independent of the risky asset’s cash flow, \( \tilde{V} \), where \( E[\tilde{Z}] \) represents the mean, or expected value, of \( \tilde{Z} \), and \( \sigma^2_z \) represents the variance of \( \tilde{Z} \). The realization \( \tilde{Z} = Z \) represents the number of shares of the risky asset that investors compete to acquire. An alternative interpretation of \( \tilde{Z} \) is that it includes both shares and trades by market participants who do not act strategically (e.g., pure liquidity traders): our results do not depend on a specific interpretation of \( \tilde{Z} \).

Expressed in equation form, market clearing requires that

\[
N \cdot D_I \left( \tilde{P}, \tilde{X} \right) + M \cdot D_U \left( \tilde{P} \right) - \tilde{Z} = 0. \tag{8}
\]

Uninformed investors are large in number but individually carry little weight in trade in shares in the risky asset. We capture this notion by assuming that \( M \) is large (i.e., \( M \) is countably infinite) and \( r_U \) is small, and the product of \( M \) and \( r_U \) converges to an arbitrary (non-negative) constant, \( \omega \): specifically, \( \lim_{M \to \infty} M \cdot r_U = \omega \). Substituting for \( D_U \) using Equation (7), in turn, implies

\[
\lim_{M \to \infty} M \cdot D_U \left( \tilde{P} \right) \to \omega \cdot \Pi_U \left( E \left[ \tilde{V} | \Phi_U \right] - P \right).
\]

The parameter \( \omega \) represents the aggregate weight of the uninformed investors in toto. For example, \( \omega \) small is tantamount to an economy where uninformed investors carry little weight
in aggregate and thus the market is primarily imperfect. Alternatively, \( \omega \) large is tantamount to an economy where uninformed investors carry considerable weight in aggregate; as such, uninformed investors supply sufficient liquidity as to make competition for asset shares approximately perfect. We regard the appropriate value of \( \omega \) for any specific economy as largely an empirical issue.

2.4 Solutions to \( \lambda \) and \( \Pi_\delta \)

To characterize the equilibrium to the economy we describe, it is sufficient to derive the solution to two endogenous variables: an informed investor’s coefficient of illiquidity, \( \lambda \), and the precision of the information uninformed investors glean from price, \( \Pi_\delta \). We begin with the derivation of \( \lambda \).

Following Kyle (1989), we assume that each informed investor adopts the strategy

\[
D_I \left( \tilde{P}, \tilde{X} \right) = \alpha + \beta \cdot \tilde{X} - \gamma \cdot \tilde{P},
\]

where \( \alpha \) is an intercept term, \( \beta \) is the weight an informed investor places on the realization of his (private) information \( \tilde{X} = X \), and \( \gamma \) is the weight an informed investor places on \( P \). For this strategy to be rational based on the computation of \( D_I \) in Equation (4), it must be the case that

\[
\begin{align*}
\alpha &= \gamma \frac{\Pi_I}{\Pi} E \left[ \tilde{V} \right], \\
\beta &= \gamma \frac{\Pi_I}{\Pi}, \quad \text{and} \\
\gamma &= \left( \frac{1}{\Pi_I} + \lambda \right)^{-1}.
\end{align*}
\]

Recall from Equation (8) that market clearing requires \( N \cdot D_I \left( \tilde{P}, \tilde{X} \right) + M \cdot D_U \left( \tilde{P} \right) - \tilde{Z} = 0 \). Substituting for \( D_I \) and \( D_U \) from Equations (9) and Equation (7), respectively, we can re-
express market clearing as the requirement that

\[ N \left( \alpha + \beta \bar{X} - \gamma \bar{P} \right) + M r_U \Pi_U \left( E \left[ \bar{V} | \Phi_U \right] - \bar{P} \right) - \bar{Z} = 0. \]

This allows price to be expressed as

\[ \bar{P} = \Delta \left( N \alpha + N \beta \bar{X} + \omega \Pi_U E \left[ \bar{V} | \Phi_U \right] - \bar{Z} \right), \tag{13} \]

where \( \Delta \) is given by

\[ \Delta = (N \gamma + \omega \Pi_U)^{-1}. \]

The expression \( \Delta \) can be thought of as the marginal impact of share demand on price.

The next step is to determine the equation that solves for \( \lambda \). This equation results from reconciling an informed investor’s strategy that \( D_I = \alpha + \beta \bar{X} - \gamma \bar{P} \) with the market-clearing condition in Equation (13). The derivation is complex, however, and thus we relegate it to the Appendix: there, see “Derivation of Equation (14).” The derivation yields the requirement that \( \lambda \) solve the following quadratic equation:

\[ \lambda^2 \omega \Pi_U r_I \Pi_I + \lambda ((N - 2) r_I \Pi_I + \omega \Pi_U) - 1 = 0. \tag{14} \]

Now we derive \( \Pi_\delta \). To derive the uninformed investors’ beliefs, recall from Equation (13) that the market clearing condition implies

\[ \bar{P} = \Delta \left( N \alpha + N \beta \bar{X} + \omega \Pi_U E \left[ \bar{V} | \Phi_U \right] - \bar{Z} \right). \]

As is standard in a RE-economy (e.g., Grossman and Stiglitz, 1980; Hellwig, 1980; Diamond and Verrecchia, 1981), we assume that each uninformed trader can manipulate the market clearing price \( \bar{P} \) to obtain information about \( \bar{V} \) through the statistic \( \bar{Q} \), where

\[ \bar{Q} = (N \Delta \beta)^{-1} \left( \bar{P} - \Delta \left( N \alpha + \omega \Pi_U E \left[ \bar{V} | \Phi_U \right] \right) \right) = \bar{X} - (N \beta)^{-1} \bar{Z} = \bar{V} + \bar{\delta}, \]
where $\tilde{\delta} = \tilde{\varepsilon} - (N\beta)^{-1} \tilde{Z}$. The statistic $\tilde{Q}$ measures an informed investor’s private information, $\tilde{X}$, with error; this makes $\tilde{Q}$ a noisier measure of $\tilde{V}$ than is $\tilde{X}$. Stated somewhat differently, an uninformed investor’s error about the realization of the asset’s cash flow $\tilde{V} = V$ is the sum of two terms: the error in $\tilde{X}$ plus the additional error in $\tilde{Q}$. Henceforth let $\Pi_\delta$ represent the precision of $\tilde{Q}$.

When an uninformed investor manipulates price to infer $\tilde{Q} = Q$, an uninformed investor’s posterior beliefs about the risky asset’s cash flow of $\tilde{V}$ is that it has an expected value of

$$
E \left[ \tilde{V} | \tilde{Q} = Q \right] = E \left[ \tilde{V} \right] + \frac{\Pi_\delta}{\Pi_v + \Pi_\delta} \left( Q - E \left[ \tilde{Q} \right] \right);
$$

in addition, an uninformed investor associates a precision of

$$
\Pi_U = \Pi_v + \Pi_\delta
$$

to these beliefs. Thus, we have to solve for $\Pi_\delta$ to determine $\Pi_U$. Note that equations (11) and (12) provide expressions for $\beta$ and $\gamma$: $\beta = \gamma \Pi_v \Pi_U$ and $\gamma = \left( \frac{1}{r_I \Pi_U} + \lambda \right)^{-1}$. Thus, the precision of $\tilde{Q}$, $\Pi_\delta$, must equal

$$
\Pi_\delta = \left( \Pi^{-1} + (N\beta)^{-2} \sigma_z^2 \right)^{-1}.
$$

(15)

We summarize our results to this point in the following lemma.

**LEMMA.** An equilibrium to the economy we posit requires that informed investors’ illiquidity coefficient, $\lambda$, and the precision of the information conveyed by price to uninformed investors, $\Pi_\delta$, satisfy the following pair of equations:

$$
\lambda^2 \omega \Pi_U r_I \Pi_I + \lambda ((N - 2) r_I \Pi_I + \omega \Pi_U) - 1 = 0 \quad \text{and} \quad (16)
$$

$$
\Pi_\delta - \left( \Pi_v^{-1} + (N\beta)^{-2} \sigma_z^2 \right)^{-1} = 0. \quad (17)
$$

**Proof.** The proof to the Lemma follows from the discussion above.
Equation (16) is the familiar “λ equation” from Kyle’s work that expresses the degree of market illiquidity in equilibrium: see, in particular, Equation (2.8) in Kyle (1985). In other words, λ measures the extent to which an informed investor anticipates that his demand order will move price in the identify \( P = p_0 + \lambda \cdot D_I \). While ostensibly a quadratic expression in λ, Equation (16) relies on \( \Pi_U \), which by definition relies on \( \Pi_\delta \); but from Equation (17) \( \Pi_\delta \) is a function of \( \beta \), which is also a function of the illiquidity parameter \( \lambda \). Therefore, unlike Kyle (1985) one cannot solve \( \lambda \) in closed form because when substitutions are made in Equation (16) for \( \Pi_U \), \( \Pi_\delta \), and \( \beta \), Equation (16) expands to a 4-th-order polynomial in \( \lambda \). That said, the intuition that underlies Equation (16) is equivalent to the intuition in Kyle (1985): Equation (16) expresses the extent to which an informed investor anticipates that his demand order will move price (in equilibrium).

Equation (17) is the incremental information that uninformed investors glean by conditioning their expectations on price, which communicates the informed investors’ private information with noise. In other words, uninformed investors manipulate the market clearing price \( \tilde{P} \) to obtain information about \( \tilde{V} \) through the statistic \( \tilde{Q} \), where \( \tilde{Q} = \tilde{V} + \tilde{\delta} \). This manipulation yields incremental knowledge about \( \tilde{V} \) (incremental to uninformed investors’ priors about \( \tilde{V} \)); Equation (17) expresses the precision of this incremental knowledge. In this sense, the intuition that underlies Equation (17) is equivalent to the intuition in Grossman and Stiglitz (1980) where price communicates (with noise) informed investors’ private information to uninformed investors. For example, see the discussion in Section D of that paper and in particular Equation (11), which the paper characterizes as a measure of “How well-informed uninformed traders can become from observing [price]...”

Equations (16) and (17) represent a system of two equations and two unknowns. In
general, these equations cannot be solved in closed form. Nonetheless, in the next subsection we establish the existence of a solution to the two equations, and therefore the existence of an equilibrium to the economy we describe.

2.5 Existence of an Equilibrium

The next result establishes the existence of an equilibrium.

THEOREM 1. A sufficient condition that there exists a unique equilibrium for the economy we posit is that there are at least three informed investors in the economy: that is, \( N \geq 3 \).\(^9\)

Proof. The proof to Theorem 1 is in the Appendix.

While \( \lambda \) and \( \Pi_s \) cannot be expressed in closed-form, nonetheless we can use equations (16) and (17) to develop insights into the properties of the equilibrium. For example, Equation (16) provides conditions where the market approaches a perfect competition setting, in which case \( \lambda \) approaches 0; it also provides conditions where \( \lambda \) is non-zero.

COROLLARY 1. Informed investors’ illiquidity coefficient, \( \lambda \), approaches 0 as either \( N \) or \( \omega \) approaches infinity: otherwise \( \lambda \neq 0 \).

Proof. The proof to Corollary 1 is in the Appendix.

Corollary 1 establishes that when the number of informed investors in the market becomes large (i.e., \( N \) becomes large), each informed investor becomes sufficiently atomless so as to behave as a price taker. This renders the market perfectly liquid, and thus informed investors behave as price-takers. Alternatively, if the aggregate weight of uninformed investors becomes large (i.e., \( \omega \) becomes large), uninformed investors dominate the market. As a re-

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\(^9\) This is consistent with Kyle (1989), who also requires that the participation of at least three investors (i.e., \( N \geq 3 \)) so as to eliminate the possibility of one investor, or a pair of investors, having too much monopoly power: see the discussion on p. 329 of Kyle (1989).
sult, they provide sufficient liquidity to absorb the trading activities of informed investors, and thus informed investors behave as price-takers. In other words, as either $N$ or $\omega$ becomes large, essentially the market becomes perfectly competitive. Absent these two conditions, the market is less than perfectly liquid.

# 3 Cost of Capital

Finally we consider the cost of capital. First we derive a general expression for the cost of capital, and then we discuss the role of information asymmetry on the cost of capital when markets are perfectly versus imperfectly competitive.

## 3.1 Cost of Capital Derived

A standard definition of an asset’s cost of capital is the extent to which investors discount price at the beginning of the period (i.e., in expectation) relative to the expected value of the asset’s cash flow (see, e.g., Easley and O’Hara, 2004). We use the investors’ demands as characterized by equations (4) and (7), along with market clearing condition, to derive $E[\ddot{P}]$ and then the cost of capital.

**THEOREM 2.** Cost of capital in the economy reduces to

$$E[\ddot{V}] - E[\ddot{P}] = \left( \frac{(1 + r_I \Pi_I \lambda)^{-1} N r_I \Pi_I + Mr_U \Pi_U}{N r_I + Mr_U} \right)^{-1} E \left[ \frac{\ddot{Z}}{N r_I + Mr_U} \right].$$

**Proof.** The proof to Theorem 2 is in the Appendix.

Note that although we continue to assume that $\lim_{M \to \infty} Mr_U = \omega$, we use the expression “$Mr_U$” in place of $\omega$ to illustrate the weight of uninformed investors, $Mr_U$, relative to informed investors, $N r_I$. Theorem 2 demonstrates that the cost of capital can be expressed
as function of the precision of each type of investor (i.e., $\Pi_I$ and $\Pi_U$), the aggregate weight of each type (i.e., $Nr_I$ and $Mr_U$), and informed investors’ illiquidity coefficient (i.e., $\lambda$).

### 3.2 Perfect Competition

In this section, we consider the expression for cost of capital in Theorem 2 when the economy is perfectly competitive. Perfect competition will result when informed and uninformed investors both represent investor classes that are made up of a very large number of very small investors; in effect, informed and uninformed investors both behave as price takers.\(^\text{10}\)

Perfect competition can also arise in our model from simply exogenously setting $\lambda$ equal to 0, which is consistent with the assumption implicitly made in most noisy RE models. With this assumption, both investor-types act as price takers, which facilitates a comparison of our results with other perfect competition papers. In this circumstance one can show that the equilibrium conditions in the Lemma in Section 2.4 reduce to $\lambda = 0$ and the requirement that $\Pi_\delta$ solves

$$
\Pi_\delta = \left(\Pi_\epsilon^{-1} + (N r_I \Pi_\epsilon)^{-2} \sigma_\zeta^2\right)^{-1}.
$$

In addition, because $\lambda = 0$, cost of capital reduces to

$$
E \left[ \hat{V} \right] - E \left[ \hat{P} \right] = \left(\frac{N r_I \Pi_I + M r_U \Pi_U}{N r_I + M r_U}\right)^{-1} E \left[ \frac{\hat{Z}}{N r_I + M r_U} \right].
$$

This establishes that cost of capital depends \textit{solely} on the inverse of investors’ average precision of information across both investor types, where the average precision of information is defined as

$$
\Pi_{avg} = \frac{N r_I \Pi_I + M r_U \Pi_U}{N r_I + M r_U}.
$$

\(^\text{10}\) As is the case for uninformed investors, here we assume that the number of informed investors, $N$, is large and their tolerance for risk, $r_I$, is small, such that the product of $N$ and $r_I$ converges to an arbitrary (non-negative) constant.
in other words, $\Pi_{avg}$ is the precision of each investor type averaged over the aggregate weight of that type, i.e., $Nr_I$ and $Mr_U$, respectively.$^{11}$

This result has a number of implications. First, consider the effect of increasing the precision of the information available to investors by boosting the amount of public information in the economy. In our analysis, increasing the amount of public information is tantamount to increasing the precision of investors’ prior beliefs through an increase in $\Pi_v$. When $\Pi_v$ increases, $\Pi_I = \Pi_v + \Pi_e$ and $\Pi_U = \Pi_v + \Pi_b$ both increase, and thus in Equation (19) $\Pi_{avg}$ increases and cost of capital declines. In other words, increasing the amount of public information lowers the cost of capital because such a change increases the average precision of investors’ information; it lowers investors’ assessment of uncertainty, thereby lowering the risk premium they demand to hold the firm’s shares.

Second, it demonstrates that in a perfect competition setting the extent to which investors’ precisions differ from the average precision has no effect on the cost of capital, holding average precision fixed.$^{12}$ For example, any change in the composition of investors’

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$^{11}$ This result also complements results in Admati (1985). While Admati (1985) does not discuss cost of capital per se, her results have implications for cost of capital. Admati shows that the average precision of investors’ private information is relevant for price, and therefore cost of capital. Admati’s (1985) information structure, however, assumes that the noise terms in each investor’s information are conditionally independent. This implies that all investors extract exactly the same amount of incremental precision from price regardless of the precision of their private signals. Therefore, the average precision of investors’ posterior distributions is a simple transformation of their average private information precisions. By assuming conditional independence of the error terms, Admati’s model precludes the possibility that some investors receive only a subset of the information signals observed by others. In contrast, our model explicitly incorporates these features, which we believe are key characteristics of information asymmetry. In our setting, investors do not learn equal amounts from price: while the less-informed type learns from price, the more-informed type does not. As a result, there is no simple transformation from the average precision of investors private information to the average precision of their posteriors. Our result shows that the average precision of posteriors is a key determinant of cost of capital.

$^{12}$ Note that the average precision in eqn. (19) is an average of investors’ equilibrium precisions, including the effect of learning from price. While there are many candidates for defining the degree of information asymmetry in the economy, the important insight is that regardless of the specific definition employed, the degree of information asymmetry has no impact on cost of capital after controlling for any impact it might have on average precision.
information between private signals and public signals affects cost of capital only through the impact of this change on average precision. Consider the analysis in Grossman and Stiglitz (1980) and Easley and O'Hara (2004). Both papers posit economies with a single risky-asset with two types of investors, more informed and less informed. For our purposes, the important feature of their models is that they both assume perfect competition among investors. Therefore, any results they attribute to changes in the information environment must operate through an effect on investors’ average precision.

Easley and O'Hara (2004) examine the effect of reducing informed investors’ information advantage by making some of their private information public. Such a change will increase the precision of less informed investors and leave unchanged the total precision of more informed investors. Easley and O'Hara (2004) correctly conclude that cost of capital declines, but interpret the result as occurring because of a reduction in information asymmetry. Our equation for cost of capital above shows that the reason this decreases cost of capital is because it increases average precision. Therefore, contrary to the conclusion of Easley and O'Hara (2004), our analysis shows that in a market of perfect competition there is no separate undiversifiable “information risk” factor that affects cost of capital. Instead, cost of capital is driven solely by the average amount of uncertainty that investors assess, and that this uncertainty is measured by their average precision regarding the distribution of cash flows.

As the example above demonstrates, a decrease in information asymmetry can reduce the cost of capital if it also increases average precision. Information asymmetry and average precision, however, need not always move simultaneously in these directions. To illustrate this point, consider the effect of an increase in the amount of private information available to informed investors. When informed investors have more private information, the precision of
their information will go up directly through an increase in $\Pi_\varepsilon$. The precision of uninformed investors will also go up, but indirectly because uninformed investors use price to infer some of the incremental private information available to informed investors. But uninformed investors’ precision will not increase at as fast a rate as informed investors’ precision because 

$$\Pi_\delta = \left( \Pi_\varepsilon^{-1} + (N r_I \Pi_\varepsilon)^{-2} \sigma_\varepsilon^2 \right)^{-1},$$

and thus

$$\frac{\partial \Pi_\delta}{\partial \Pi_\varepsilon} = \frac{N^2 r_I^2 \Pi_\varepsilon \Pi_\varepsilon - 2 \sigma_\varepsilon^2}{(N^2 r_I^2 \Pi_\varepsilon + \sigma_\varepsilon^2)^2} < 1.$$ 

Hence, more private information to informed investors will result in more information asymmetry between informed and uninformed investors. Despite the fact that information asymmetry increases, our results demonstrate that the cost of capital goes down, not up, because more private information to informed investors will increase investors’ average precision.

To further demonstrate the distinction between information asymmetry and average precision, consider the seminal work of Grossman and Stiglitz (1980). A key feature of this paper’s model is that the proportion of investors who end up as the more-informed type is endogenous. Holding constant the precision of the information of each investor type, an increase in the proportion of the more-informed type will increase the average precision of investors’ information. Such a change, however, has an non-monotonic effect on the degree of information asymmetry in the economy. In particular, there is no information asymmetry at either of the extremes: for example, when all the investors are of the more-informed type or all investors are of the less-informed type. Therefore, average precision and information asymmetry do not move in concert in response to changes in the information environment. Moreover, because the analysis in Grossman and Stiglitz (1980) is couched in terms of a model of perfect competition, our results imply that any more general changes in the infor-
mation structure that lead to a change in the endogenous proportion of informed investors only affect cost of capital if this change also affects average precision.

Taken together, these implications show that in an economy with perfect competition, attempts at leveling the playing field by providing all investors with the same information have an ambiguous effect on the cost of capital. If the playing field is leveled by increasing the information available to the less-informed type, the cost of capital goes down. If the playing field is leveled by restricting the ability of informed investors to acquire additional private information, then the cost of capital will rise. In summary, in a perfect competition setting the communication of more information to more investors, not the reduction of information asymmetry per se, lowers the cost of capital.

3.3 Imperfect Competition

When $\lambda \neq 0$, Theorem 2 implies that illiquidity can affect the cost of capital in two ways. First, when $\lambda \neq 0$, the “weighting” scheme applied to investors in the cost of capital equation is not the simple weighted average of the precisions of the two investor types. That is, under perfect competition, investors do not have to worry about the impact of their trades on price, and each investor’s demand is proportionate to the product of his risk tolerance, $r_t$, and precision, $\Pi_t$, $t \in \{I, U\}$. Therefore, in summing their demands to achieve market clearing, the precision of information of each investor type is weighted in proportion to the type’s aggregate risk tolerance. Under imperfect competition, the weight assigned to the precision of the uninformed type is still its aggregate risk tolerance, $Mr_U$. The weight assigned to the precision of the informed type, however, is now $(1 + r_I\Pi_I\lambda)^{-1} Nr_I$ instead of $Nr_I$; one can think of the term $(1 + r_I\Pi_I\lambda)^{-1}$ as a “reduction” factor arising from market illiquidity.
This reduction also arises because informed investors have to curb the aggressiveness of their demands because of market illiquidity. Thus, informed investors’ private information does not get impounded or reflected in price as fully as the precision of their information (and their aggregate weight) might imply. Because the informed type has greater precision, and this precision is reduced because of market illiquidity, this also implies that market illiquidity leads to higher cost of capital, ceteris paribus.

Second, the greater the degree of illiquidity faced by informed investors, the less aggressively informed investors trade on the basis of their private information; hence, the less uninformed investors learn by conditioning their expectations on price. Therefore, ceteris paribus, greater market illiquidity lowers the precision of information held by the less informed type.\textsuperscript{13} This lowers investors’ average precision of information, and thus raises the cost of capital.

We reconcile our discussion here with the prior discussion of perfect competition by offering numerical examples in the Appendix that illustrate that information asymmetry can increase the cost of capital when markets are not perfectly liquid even in a circumstance where investors’ average precision of information stays fixed. As discussed in the prior subsection, this cannot happen when markets are perfectly competitive: when competition is perfect, cost of capital does not change when investors’ average precision stays fixed. This result implies that in explaining the behavior of cost of capital, in perfect competition settings information asymmetry has no additional explanatory power over-and-above the explanatory power of investors’ average precision. Alternatively, in imperfect competition

\textsuperscript{13} Although beyond the scope of our analysis, if the precision of the information available to informed investors was a choice variable, it is likely they would acquire less information as the market became more illiquid. This would further reduce the average precision of information across investors.
settings, information asymmetry has additional explanatory power.

4 Implications for Empirical Work

Our analysis has implications regarding two types of potential empirical misspecifications. First, empirical studies that employ proxies for “information risk” and “accounting quality” often implicitly or explicitly assume their proxies are capturing a measure of information asymmetry. These proxies, however, are often also related to the overall precision of information available to investors. Unfortunately, the fact that average precision and information asymmetry are different concepts in theory does not necessarily mean that they are easy to distinguish in practice. Empirically, average precision and information asymmetry may both change simultaneously, making it difficult to distinguish one from the other. That said, it is important to emphasize two points. First, the fact that it may be difficult to distinguish average precision from information asymmetry in practice is not an argument that information asymmetry affects cost of capital. Rather, it is merely a claim that the two effects may be hard to distinguish empirically. Second, there is no logical reason to believe that average precision and information asymmetry always move in concert. As discussed above, it is easy to give examples where they do not.

Consider, for example, Regulation FD (Reg FD). Prohibiting private communication

14 For instance, Aslan, Easley, Hvidkjaer, and O’Hara (2008) define information risk as arising “when some investors have better information than others about the prospects of a firm.” As such, information risk is generally viewed as closely linked to information asymmetry.

15 This comment applies to proxies ranging from the number of analysts covering a firm, to the quality of their reported earnings, to the Probability of an Informed Trade (PIN). For example, PIN depends on, amongst other things, the likelihood investors obtain private information, which generally also depends on the quality of publicly available information.

16 Verdi (2005) shows that many commonly used information proxies load onto distinct factors in a principal factor analysis, thereby providing evidence consistent with the notion that information asymmetry and average precision are distinct constructs.
between managers and analysts is likely to result in a reduction of information asymmetry across investors in the marketplace. If one believes that reducing information asymmetry also reduces cost of capital, then Reg FD should result in cost of capital going down. There is reason to believe, however, that the restrictions imposed by Reg FD reduce the total information available to investors. As the total declines so does investors’ average precision; in this event our analysis predicts that cost of capital will rise. Therefore, whether cost of capital is related to average precision or information asymmetry has opposite (and testable) implications. Moreover, our analysis suggests that the concern about selective disclosure is less relevant to firms that are heavily followed by analysts and very actively traded. For these firms, the effect of Reg FD on the cost of capital is governed primarily by the regulation’s effect on the average precision of investor information. But for smaller, less followed stocks, the effect of Reg FD on information asymmetry could in turn affect firms’ cost of capital, over and above any effects on the average level of information in the economy.

Similar contrasting predictions exist in an examination of relaxing (or tightening) restrictions on insider trading. Allowing insiders to trade on their information will increase information asymmetry, but will also increase the average precision of information among investors in toto; here, our analysis predicts a decrease in cost of capital. We trust that empiricists are likely to find yet more settings that result in distinct proxies for average precision and information asymmetry with contrasting predictions. Related to this distinction, Bhattacharya et al. (2009) provides evidence of separate effects using path analysis to decompose the association between earnings quality and the cost of capital. This evidence suggests both a direct path to the cost of capital, consistent with a precision effect, and an indirect path mediated by information asymmetry.
A second important implication of our analysis is that, in perfect competition settings, there is no separate, systematic risk factor in price that stems from private information or information asymmetry, as for instance claimed in Easley and O’Hara (2004). More generally, our analysis provides the testable prediction that information asymmetry plays a larger role in cost of capital if firms’ shares trade in markets that are characterized by imperfect competition. Armstrong et al. (2011) explores this idea empirically and finds that information asymmetry has a positive relation with firms’ cost of capital in excess of standard risk factors when markets are imperfect, and no relation when markets approximate perfect competition. Thus, consistent with our theoretical prediction, Armstrong et al. (2011) shows that the degree of market competition is an important conditioning variable when examining the relation between information asymmetry and cost of capital (see also Akins, Ng and Verdi, 2011). This insight is also relevant for the recent debates over whether accruals quality or the probability of informed trade (PIN) are priced in expected returns (e.g., Liu and Wysocki, 2007; Core et al., 2008; Ogneva, 2008; Easley et al., 2002 and 2010; Aslan et al., 2008; Mohanram and Rajgopal, 2009, respectively). The conflicting results in this literature could also be related to the fact that these studies typically do not condition on market competition.

5 Conclusion

This paper analyzes the role of information asymmetry in the determination of a firm’s cost of capital. Information asymmetry among investors has been a long-standing concern to securities regulators and it has also been much debated in the literature. To contribute to this debate, the paper posits an imperfect competition setting where risk-averse investors
have rational expectations about the market process. In an imperfect competition setting, investors’ demand for an asset’s shares can affect the price at which their demand is fulfilled. That is, the market is not perfectly liquid and there are costs to trading. This cost is endogenously determined as part of the equilibrium, and it occurs through an increase in price that must be paid when investors wish to buy more shares. Similarly, informed investors understand that attempts to sell more shares will lower the price they receive.

Our analysis demonstrates that there is an important interaction between imperfect competition and asymmetric information with respect to firms’ cost of capital. When markets are imperfectly competitive, the degree of market illiquidity influences the amount of information that is reflected in prices; this, in turn, reduces investors’ average precision and thus raises the cost of capital. Moreover, the degree of information asymmetry in the economy influences the amount of market illiquidity, which also raises the cost of capital. Therefore, even after controlling for investors’ average precision, the interaction between imperfect competition and asymmetric information can have an impact on the cost of capital.

In contrast, when markets are perfectly competitive, only the average precision of investors’ information is relevant. Information asymmetry, however it is defined, does not affect the cost of capital. Why is there no information asymmetry effect and why do less-informed investors not protect against more informed investors? Under perfect competition, each investor’s demand for the shares of a firm is increasing in the precision of his information. While less-informed investors demand fewer shares when they perceive uncertainty to be high, more-informed investors demand more shares. As demand is linear in each investor’s precision, when investors’ demands are aggregated the only thing that matters is the average precision of information. Moreover, the discount for risk is not greater when
the investor perceives that other investors possess more precise information. In fact, when investors condition their expectations over price in determining their demand, an investor’s degree of uncertainty decreases when other investors acquire more information because this information becomes (partially) communicated through price. Importantly, no trading takes place until an equilibrium price is set. Less-informed investors can transact any quantity at this market clearing price. In addition, they are able to use price as a conditioning variable in setting their expectations and assessing risk when they submit their demand order. As a result of these features, information asymmetry has no effect on the cost of capital and does not result in adverse selection with perfect competition.

Our analysis and results have two important implications. First, in perfect competition settings, information asymmetry does not give rise to a separate (or additional) risk factor, and there is no compensation for being less informed, as claimed in Easley and O’Hara (2004). Second, it is important to distinguish between information asymmetry and information precision, as well as to recognize that the effect of information asymmetry on the cost of capital depends on the nature of capital market competition.
Appendix

Derivation of Equation (14). Equation (14) is derived from reconciling an informed investor’s strategy that \( D_I = \alpha + \beta \tilde{X} - \gamma \tilde{P} \) with the market-clearing condition in Equation (13). This reconciliation requires that \( \tilde{p}_0 \) in the expression \( \tilde{P} = \tilde{p}_0 + \lambda D_I \left( \tilde{P}, \tilde{X} \right) \) must be of the form

\[
\tilde{p}_0 = \lambda \left( (N - 1) \alpha + (N - 1) \beta \tilde{X} + \omega \Pi_U E \left[ \tilde{V} \mid \Phi_U \right] - \tilde{Z} \right), \tag{A1}
\]

where

\[
(1 + \lambda \gamma)^{-1} \lambda = \Delta = (N \gamma + \omega \Pi_U)^{-1}.
\]

To illustrate the reconciliation, note that Equation (A1) implies

\[
\begin{align*}
\tilde{P} & = \tilde{p}_0 + \lambda D_I \left( \tilde{P}, \tilde{X} \right) \\
& = \lambda \left( (N - 1) \alpha + (N - 1) \beta \tilde{X} + \omega \Pi_U E \left[ \tilde{V} \mid \Phi_U \right] - \tilde{Z} \right) + \lambda \left( \alpha + \beta \tilde{X} - \gamma \tilde{P} \right) \\
& = \lambda \left( N \alpha + N \beta \tilde{X} + \omega \Pi_U E \left[ \tilde{V} \mid \Phi_U \right] - \tilde{Z} \right) - \lambda \gamma \tilde{P},
\end{align*}
\]

which, in turn, implies

\[
\tilde{P} = (1 + \lambda \gamma)^{-1} \lambda \left( N \alpha + N \beta \tilde{X} + \omega \Pi_U E \left[ \tilde{V} \mid \Phi_U \right] - \tilde{Z} \right); \tag{A2}
\]

Equation (A2) reconciles with the market-clearing condition in Equation (13) when \( (1 + \lambda \gamma)^{-1} \lambda = \Delta = (N \gamma + \omega \Pi_U)^{-1} \), or

\[
\lambda (N \gamma + \omega \Pi_U) = 1 + \lambda \gamma. \tag{A3}
\]

Because \( \gamma = \left( \frac{1}{r_I \Pi_I} + \lambda \right)^{-1} \), we can express Equation (A3) as

\[
\begin{align*}
\lambda \left( N + \omega \Pi_U \left( \frac{1}{r_I \Pi_I} + \lambda \right) \right) & = \frac{1}{r_I \Pi_I} + 2 \lambda. \tag{A4}
\end{align*}
\]
Equation (A4) yields the following quadratic equation that solves for \(\lambda\):

\[
\lambda^2 \omega \Pi_U r_I \Pi_I + \lambda ((N - 2) r_I \Pi_I + \omega \Pi_U) - 1 = 0.
\] (14)

Q.E.D.

**Proof of Theorem 1.** To prove Theorem 1, we have to solve Equation (17) to determine an expression for \(\Pi_\delta\) as a function of \(\lambda\), and then substitute this expression into Equation (16) to solve for \(\lambda\). This requires some tedious calculation that eventually yields the following 4\(^{th}\)-order polynomial in \(\lambda\):

\[
\begin{align*}
& r_I^3 \omega \sigma^2_z (\sigma^2_v + \sigma^2_\varepsilon)^\lambda^3 + r_I^4 \sigma^2_v \sigma^2_\varepsilon \left(\sigma^2_v + \sigma^2_\varepsilon\right)^2 \left(r_I \left(\sigma^2_v + \sigma^2_\varepsilon\right) (N - 2) + 3\omega \sigma^2_\varepsilon\right) \lambda^3 \\
& + r_I \sigma^4_v \left(\sigma^2_v + \sigma^2_\varepsilon\right) \left((3\sigma^2_v + N^2 r_I^2 \left(\sigma^2_v + \sigma^2_\varepsilon\right)) \omega + r_I \sigma^2_v \sigma^2_\varepsilon \left(\sigma^2_v + \sigma^2_\varepsilon\right) (2N - 5)\right) \lambda^2 \\
& + \sigma^6_\varepsilon \left((N^2 r_I^2 \left(\sigma^2_v + \sigma^2_\varepsilon\right) + \sigma^2_\varepsilon \sigma^4_\varepsilon) \omega + r_I \left(\sigma^2_v + \sigma^2_\varepsilon\right) \left(\sigma^2_\varepsilon \sigma^2_\varepsilon (N - 4) + N^2 r_I^2 (N - 2)\right)\right) \lambda \\
& - \sigma^8_\varepsilon \sigma^4_\varepsilon \left(\sigma^2_v \sigma^2_\varepsilon + N^2 r_I^2\right) = 0. \quad (A5)
\end{align*}
\]

Next, we re-express Equation (A5) as a 4\(^{-}\)th-order polynomial function \(F(\lambda)\):

\[
\begin{align*}
& F(\lambda) = r_I^3 \omega \sigma^2_z (\sigma^2_v + \sigma^2_\varepsilon)^\lambda^3 + r_I^4 \sigma^2_v \sigma^2_\varepsilon \left(\sigma^2_v + \sigma^2_\varepsilon\right)^2 \left(r_I \left(\sigma^2_v + \sigma^2_\varepsilon\right) (N - 2) + 3\omega \sigma^2_\varepsilon\right) \lambda^3 \\
& + r_I \sigma^4_v \left(\sigma^2_v + \sigma^2_\varepsilon\right) \left((3\sigma^2_v + N^2 r_I^2 \left(\sigma^2_v + \sigma^2_\varepsilon\right)) \omega + r_I \sigma^2_v \sigma^2_\varepsilon \left(\sigma^2_v + \sigma^2_\varepsilon\right) (2N - 5)\right) \lambda^2 \\
& + \sigma^6_\varepsilon \left((N^2 r_I^2 \left(\sigma^2_v + \sigma^2_\varepsilon\right) + \sigma^2_\varepsilon \sigma^4_\varepsilon) \omega + r_I \left(\sigma^2_v + \sigma^2_\varepsilon\right) \left(\sigma^2_\varepsilon \sigma^2_\varepsilon (N - 4) + N^2 r_I^2 (N - 2)\right)\right) \lambda \\
& - \sigma^8_\varepsilon \sigma^4_\varepsilon \left(\sigma^2_v \sigma^2_\varepsilon + N^2 r_I^2\right).
\end{align*}
\]

Here, note that \(F(\lambda = 0) < 0\) and \(\lim_{\lambda \to -\infty} F(\lambda) > 0\); this implies that there exists some positive \(\lambda\), say \(\lambda^*\), such that \(F(\lambda^*) = 0\). As for uniqueness, in \(F(\lambda)\) the coefficients for \(\lambda^j, j = 2, 3, 4\), are all positive whenever \(N \geq 3\), and the coefficient for \(\lambda^0\) is negative, i.e., \(-\sigma^8_\varepsilon \sigma^4_\varepsilon \left(\sigma^2_v \sigma^2_\varepsilon + N^2 r_I^2\right)\) is negative. In addition, the coefficient for \(\lambda^1\) is either positive or
negative when $3 \leq N \leq 4$ (and positive when $N > 4$); whichever is the case, $F(\lambda)$ has at most one sign change when $\lambda$ is positive. Thus, Descartes’ Rule of Signs dictates that $F(\lambda)$ can have at most one positive, real-valued root, provided that $N \geq 3$. Thus, there exists a unique, positive $\lambda^*$ such that $F(\lambda^*) = 0$. Having solved for $\lambda$ in Equation (A5), note that we can express $\Pi_\delta$ using Equation (17) as follows:

$$\Pi_\delta = \frac{N^2 r_\delta^2 \sigma_v^4}{r_\delta^2 \sigma_v^2 (\sigma_v^2 + \sigma_\delta^2)^2 \lambda^2 + 2 r_\delta \sigma_v^2 \sigma_\delta^2 (\sigma_v^2 + \sigma_\delta^2) \lambda + \sigma_\delta^4 \sigma_v^2 (N^2 r_\delta^2 + \sigma_v^2 \sigma_\delta^2)}.$$  \hspace{1cm} \text{(A6)}$$

Q.E.D.

Proof of Corollary 1. Recall that Equation (16) is given by

$$\lambda^2 \omega \Pi_U r_I \Pi_I + \lambda ((N - 2) r_I \Pi_I + \omega \Pi_U) - 1 = 0.$$  

Dividing this expression by $N$ yields

$$\frac{1}{N} \lambda^2 \omega \Pi_U r_I \Pi_I + \lambda \left( \left(1 - \frac{2}{N}\right) r_I \Pi_I + \omega \Pi_U \frac{1}{N} \right) - \frac{1}{N} = 0.$$  

Taking the limit as $N$ approaches infinity implies $\lambda = 0$. Similarly, dividing Equation (16) by $\omega$ yields

$$\lambda^2 \Pi_U r_I \Pi_I + \lambda \left( \left(\frac{N - 2}{\omega}\right) r_I \Pi_I + \Pi_U \right) - \frac{1}{\omega} = 0.$$  

Taking the limit as $\omega$ approaches infinity yields $\lambda^2 \Pi_U r_I \Pi_I + \lambda \Pi_U = 0$, which implies $\lambda = 0$. Finally, suppose $N$ and $\omega$ are both finite. Then if $\lambda = 0$, Equation (16) becomes $-1 = 0$, which is a contradiction. Q.E.D.

Proof of Theorem 2. Market clearing implies

$$N \cdot D_I \left( \tilde{P}, \tilde{X} \right) + M \cdot D_U \left( \tilde{P} \right) - \tilde{Z} = 0.$$  

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Substituting for $D_I$ and $D_U$ implies

$$N \cdot \left( \frac{1}{r_I \Pi_I} + \lambda \right)^{-1} \left( E \left( \hat{V} | \Phi_I \right) - \hat{P} \right) + M \cdot r_U \Pi_U \left( E \left( \hat{V} | \Phi_U \right) - \hat{P} \right) - \hat{Z} = 0.$$ 

Re-arranging terms yields

$$N \left( \frac{1}{r_I \Pi_I} + \lambda \right)^{-1} E \left( \hat{V} | \Phi_I \right) + M r_U \Pi_U E \left( \hat{V} | \Phi_U \right) - \left( N \left( \frac{1}{r_I \Pi_I} + \lambda \right)^{-1} + M r_U \Pi_U \right) \hat{P} - \hat{Z} = 0.$$ 

Solving for $\hat{P}$ results in

$$\hat{P} = \left[ N \left( \frac{1}{r_I \Pi_I} + \lambda \right)^{-1} + M r_U \Pi_U \right]^{-1} \times \left[ N \left( \frac{1}{r_I \Pi_I} + \lambda \right)^{-1} E \left( \hat{V} | \Phi_I \right) + M r_U \Pi_U E \left( \hat{V} | \Phi_U \right) - \hat{Z} \right].$$ 

Taking expected values and using the law of iterated expectations implies $E \left[ E \left( \hat{V} | \Phi_I \right) \right] = E \left[ E \left( \hat{V} \right) \right]$, or

$$E \left[ \hat{P} \right] = E \left[ \hat{V} \right] - \left[ N \left( \frac{1}{r_I \Pi_I} + \lambda \right)^{-1} + M r_U \Pi_U \right]^{-1} E \left[ \hat{Z} \right]$$

$$= E \left[ \hat{V} \right] - \left[ \frac{N \left( \frac{1}{r_U \Pi_U} + \lambda \right)^{-1} + M r_U \Pi_U}{N r_I + M r_U} \right]^{-1} E \left[ \hat{Z} \right] \frac{N r_I + M r_U}{N r_I + M r_U}.$$ 

Finally we substitute $\left( \frac{1}{r_I \Pi_I} + \lambda \right)^{-1} = (1 + r_I \Pi_I \lambda)^{-1} r_I \Pi_I$ to get

$$E \left[ \hat{P} \right] = E \left[ \hat{V} \right] - \left[ \frac{(1 + r_I \Pi_I \lambda)^{-1} N r_I \Pi_I + M r_U \Pi_U}{N r_I + M r_U} \right]^{-1} E \left[ \hat{Z} \right] \frac{N r_I + M r_U}{N r_I + M r_U}.$$ 

Q.E.D.

**Numerical examples**

Here we provide numerical examples that illustrates the change in the cost of capital that results from a change in information asymmetry, while holding the average precision of investors’ information fixed. In order to change the degree of information asymmetry while
holding investors’ average precision fixed, at least two exogenous variables must change simultaneously while also calibrating the magnitude of these changes. As this is computationally challenging, we illustrate this with a numerical example. To explain these examples, \( \lambda \) and \( \Pi_\delta \), as endogenous variables, could be thought of as functions of 6 exogenous variables: \( N \), the number of informed investors; \( r_I \), the risk tolerance of informed investors; \( \omega \), the aggregate weight of uninformed investors; \( \sigma_v^2 \), the a priori variance of the risky asset’s cash flow; \( \sigma_\varepsilon^2 \), the variance in the error in informed investors’ private information; and \( \sigma_z^2 \), the variance in the supply of shares of the risky asset. Thus, first we specify values for the 6-tuple \( \Omega = (N, r_I, \omega, \sigma_v^2, \sigma_\varepsilon^2, \sigma_z^2) \), then we solve for \( \lambda \) and \( \Pi_\delta \), and finally we compute investors’ average precision and the cost of capital using equations (19) and (18), respectively.

To start, consider an economy with four informed investors, \( N = 4 \), who have a risk tolerance of 1 (i.e., \( r_I = 1 \)). Let the aggregate weight of the uninformed investors converge to 1 as their number becomes large (i.e., \( \lim_{M \to \infty} Mr_U = \omega \to 1 \)). We assume that the a priori variance of the risky asset’s cash flow is \( \sigma_v^2 = 1 \). We begin with the assumptions that \( \sigma_\varepsilon^2 = 1 \) and \( \sigma_z^2 = 1 \); these assumptions imply that the precision of the information available to informed investors is \( \Pi_I = \Pi_v + \Pi_\varepsilon = 2 \). Using Equation (A5), we compute \( \lambda = 0.15409 \). This, in turn, implies from Equation (A6) that the precision of the information an uninformed investor gleans from price is \( \Pi_\delta = 0.9034 \), and the (total) precision of the information available to uninformed investors is \( \Pi_U = \Pi_v + \Pi_\delta = 1.9034 \). Using Equation (19), investors’ average precision computes to \( \Pi_{\text{avg}} = 1.9807 \). In addition, using Equation (18) in Theorem 2 the risky asset’s cost of capital computes to

\[
0.12471 \cdot E \left[ \hat{Z} \right].
\]
Now consider a circumstance where an informed investor acquires more private information, but the average precision of information remains at the same level. For example, suppose $\sigma_{\tilde{z}}^2$ falls from $\sigma_{\tilde{z}}^2 = 1$ to $\sigma_{\tilde{z}}^2 = 0.9$, which implies that the precision of an informed investor’s private information increases: specifically, $\Pi_I = 2.1111$. In order for average precision of information to remain at the same level, we now require the variance of the liquidity shock to increase such that $\sigma_{\tilde{z}}^2$ rises to $\sigma_{\tilde{z}}^2 = 14.034$. This causes $\lambda$ to increase to 0.16183. This, in turn, implies that the precision of the information an uninformed investor gleans from the price drops to $\Pi_{\delta} = 0.459$, and the (total) precision of the information available to uninformed investors is $\Pi_{U} = \Pi_0 + \Pi_{\delta} = 1.459$. Here, investors’ average precision remains at the same level: $\Pi_{\text{avg}} = 1.9807$. In other words, investors have the same average precision of $\Pi_{\text{avg}} = 1.9807$ for both the 6-tuples $\Omega = (4,1,1,1,1,1)$ and $\Omega = (4,1,1,1,.9,14.034)$.

Despite the fact that the average precision does not change, the increase in information asymmetry between the two investor types manifests in greater illiquidity: specifically, $\lambda$ increases from 0.15409 to 0.16183. This, in turn, results in higher cost of capital. Specifically, when $\Omega = (4,1,1,1,.9,14.034)$ the risky asset’s cost of capital rises to

$$0.12898 \cdot E\left[ \tilde{Z} \right].$$

This demonstrates that in our imperfect competition setting, cost of capital increases as information asymmetry increases, despite the fact that average precision remains unchanged. Thus, we find a role for information asymmetry in cost of capital through its effect on market illiquidity - this role does not exist in perfect competition settings.
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Verdi, R. (2005), Information environment and the cost of capital, unpublished working paper, Massachusetts Institute of Technology.

Table 1 - Notation

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N, M$</td>
<td>number of informed and uninformed investors, respectively</td>
</tr>
<tr>
<td>$r_I, r_U$</td>
<td>risk tolerances of informed and uninformed investors, respectively</td>
</tr>
<tr>
<td>$\Phi_I = {\hat{P} = P, \hat{X} = X}$</td>
<td>information available to informed investors</td>
</tr>
<tr>
<td>$\Phi_U = {\hat{P} = P}$</td>
<td>information available to uninformed investors</td>
</tr>
<tr>
<td>$D_I, D_U$</td>
<td>an informed and uninformed investor’s demand for shares in the risky asset, respectively</td>
</tr>
<tr>
<td>$\omega$</td>
<td>the product of $M$ and $r_U$ as $M$ becomes large</td>
</tr>
<tr>
<td>$\hat{V}$</td>
<td>cash flow of the risky asset</td>
</tr>
<tr>
<td>$\hat{P}$</td>
<td>price of shares in the risky asset</td>
</tr>
<tr>
<td>$\hat{Z}$</td>
<td>supply of shares in the risky asset</td>
</tr>
<tr>
<td>$\sigma_v^2$</td>
<td>a priori variance of the asset’s cash flow</td>
</tr>
<tr>
<td>$\sigma_z^2$</td>
<td>variance of shares in the risky asset</td>
</tr>
<tr>
<td>$\sigma_z^2$</td>
<td>variance of the error in informed investors’ private information</td>
</tr>
<tr>
<td>$\Pi_I = \Pi_v + \Pi_c$</td>
<td>precision of informed investors’ beliefs about the risky asset’s cash flow</td>
</tr>
<tr>
<td>$\beta$</td>
<td>the sensitivity of an informed investor’s demand to private information</td>
</tr>
<tr>
<td>$\tilde{p}_0$</td>
<td>intercept in $\hat{P}$ unrelated to an informed investor’s demand</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>an informed investor’s coefficient of illiquidity</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>intercept term in an individual investor’s demand for firms’ shares</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>coefficient that measures the extent to which an investor’s demand moves price</td>
</tr>
<tr>
<td>$\Pi_U = \Pi_v + \Pi_\delta$</td>
<td>precision of uninformed investors’ beliefs about the risky asset’s cash flow</td>
</tr>
<tr>
<td>$\Delta$</td>
<td>marginal impact on price of share demand</td>
</tr>
<tr>
<td>$\Pi_{avg}$</td>
<td>investors’ average precision of information</td>
</tr>
</tbody>
</table>