"Microstructure and Ambiguity"

by

David Easley
Department of Economics
Cornell University

and

Maureen O'Hara
Johnson Graduate School of Management
Cornell University

January 2006
Revised April 2007

We would like to thank Scott Condie, Carole Gresse, Thiery Foucault, Tim Riddiough, Gideon Saar, and seminar participants at Collegio Carlo Alberto, Cornell, HKUST, ISCTE, Singapore Management University, the University of Miami, the University of Porto, the University of Wisconsin, and the Euronext – Universite Paris Dauphine conference (March 2006) for helpful comments and suggestions. The authors can be reached at dae3@cornell.edu and mo19@cornell.edu.

Microstructure and Ambiguity

Abstract

A general goal for stock exchanges is to increase participation by firms and investors. Recent research has highlighted the role of ambiguity in affecting participation. In this research, we show the role that microstructure can play in reducing the ambiguity confronting traders. We develop a model with objective expected utility maximizing traders and naive traders, and we show how these naïve traders can choose to participate or not participate in markets. We then show how specific features of the microstructure can reduce the perceived ambiguity, and induce participation by both firms and issuers Our analysis demonstrates how designing markets to reduce ambiguity can benefit investors through greater liquidity, exchanges through greater volume, and issuing firms through a lower cost of capital.

"Microstructure and Ambiguity"

1. Introduction

A general goal for stock exchanges is to increase participation by firms and investors. There is a direct reason for doing so as exchanges make money off of trade executions and listing fees, and both of these are increased by greater participation.[1] But there is also an indirect channel as more volume begets lower spreads, which lowers execution costs, which induces more volume, which then generates more profits. This cycle suggests that exchanges and investors alike gain from greater participation, and even the economy may benefit from increased participation in stock markets if it can lower the equity premium.[2] How then to increase participation in a market?

We know from a growing body of research (see, for example, Gilboa and Schmeider [1989]; Cao, Wang and Zhang [2003]; Easley and O'Hara [2005]) that a factor influencing participation is ambiguity aversion.[3] Traders with ambiguity aversion opt not to participate when the ambiguity, or uncertainty, in a market is high. Such a problem arises when traders believe that adverse distributions of cash flows are possible, even when these outcomes are objectively unlikely. In this paper, we look at how features of the microstructure can reduce ambiguity and thereby enhance participation in an equity market.

---

[1] Exchange revenues arise from multiple sources. These include fees collected from members or specialists, regulatory fees, explicit execution fees, and tape revenue (income that arise from selling quote and trade data) which is often a substantial fraction of the exchanges overall revenue. These latter two sources of revenue are strictly increasing in volume, resulting in exchange profits being largely volume driven.

[2] Models in which participation affects the equity premium include Merton [1987]; Basak and Cuoco [1998]; Brav, Constantinides, and Geczy [2002]; Vissing-Jorgenson [2002]; Easley and O'Hara [2004]; and Cao, Wang and Zhang [2005].

[3] Ambiguity aversion, also known as Knightian uncertainty, arises when traders distinguish between risk and uncertainty in their decision-making. When traders are unable to attach probabilities to the occurrence of particular outcomes, they may purse decision-rules that maximize the minimum expected utility across possible states. This results in traders attaching undue importance to unlikely outcomes, and induces non-participation. See Gilboa and Schmeidler [1989]; Ghirardato, Maccheroni, and Marinacci [2004]; or Klibanoff, Marinacci, and Mukerji [2004] for greater analysis.

Linking microstructure to ambiguity seems particularly appropriate given that ambiguity aversion is often ascribed to naïve investors. For an exchange, attracting these naïve investors essentially adds uninformed order flow, and this in turn enhances the liquidity of the market.[4] We develop a model with objective expected utility maximizing traders and naive traders, and we show how these naïve traders can choose to participate or not participate in markets. We then show how specific features of the microstructure can reduce the perceived ambiguity, and induce participation by both firms and issuers.[5] For our purposes here, we define the microstructure of the market as including market rules, trading systems, and trading procedures. Our analysis demonstrates how designing markets to reduce ambiguity can benefit investors through greater liquidity, exchanges through greater volume, and issuing firms through a lower cost of capital.

An immediate application of our research is to provide insights into the function and design of markets. The advent of technology has transformed the competitive landscape for stock exchanges from what was a relatively protected, monopolistic institution into a highly competitive, dynamic industry.[6] This change has resulted in a plethora of trading venues, and it has forced exchanges to compete for issuers and investors alike. Our analysis shows the competitive role played by features such as listing standards, trading halts, and market rules and procedures. There is a large and important literature in microstructure looking at such issues (recent examples include Parlour and Seppi [2003]; Foucault and Parlour [2004]; and Chemmanur and Fulghieri [2005]), with much of this research focusing on how the microstructure affects the price discovery and liquidity production role of markets. Our work is

[4] Ahn, et al [2006] provide a careful empirical analysis showing the positive effects of greater small trader participation on market liquidity, execution costs, and trading volume in the Tokyo Stock Exchange.
[5] These specific features could include listing rule (blue sky protection); delisting rules (fraud); trading halts; affirmative obligations of market makers (liquidity); transparency; price collars and daily limits; public comes first rules; clearing house rules and margin requirements; fast market rules, etc.
[6] These market changes and their impact on exchanges are discussed in O'Hara [2004].

the first that we are aware of to focus on the role and impact of market design in reducing ambiguity, or uncertainty. We demonstrate how this added dimension can have important implications for market design.

Our analysis also demonstrates how firms may sort out between listed markets (stock exchanges), and between listed markets and unlisted markets such as the Pink Sheets. As we demonstrate, for some firms, the costs of exchange listing are more than offset by the benefits arising from their increased attractiveness to investors, resulting in a lower cost of capital for the firm. For other firms, particularly those for whom ambiguity is either very high or very low, exchange listing brings few benefits but can entail substantial costs. Our results here provide one explanation for why the Pink Sheets include such market titans as Nestle and Volkswagen, as well as virtually unknown firms such as Kahala Corporation and O'Sullivan Industries. On a more topical issue, our analysis also explains why so many firms have now shifted to unlisted venues in the wake of the Sarbanes-Oxley reforms, and why such reforms have also reduced the attractiveness of U.S. exchanges for new offerings. Our results also suggest particular microstructure features that may prove effective in inducing foreign investors to hold stocks in emerging economies.

Perhaps the most important result of our research is to demonstrate a new channel whereby microstructure matters for real economic variables. Researchers have increasingly argued that liquidity and information risk affect asset prices, providing an importance to the microstructure surrounding the trading of assets.[7] In this research, we show how microstructure can reduce the ambiguity confronting traders, and how this, in turn, can affect asset prices and, by extension, a firm's cost of capital. What underlies our analysis is the influence of

[7] For research linking liquidity to asset pricing, see Chordia, Roll and Subrahmanyam [2000], Chordia, Sarkar, and Subrahmanyam [2005], and Pastor and Stambaugh [2003]. The role of information risk in asset pricing is found in Easley, Hvidkjaer, and O'Hara [2003]; O'Hara [2003]; and Easley and O'Hara [2004].

microstructure variables on trader participation. As stressed by Campbell [2006], nonparticipation in equity markets is empirically large, and economically detrimental.[8] Our analysis develops one explanation for why this problem arises, and more importantly, provides a range of microstructure solutions for reducing it.[9]

This paper is organized as follows. The next section provides a brief overview of ambiguity aversion, and its implications for decision making. Section 3 then sets out a model of trading which includes sophisticated (objective expected utility maximizing) traders, naïve (ambiguity averse) traders, firms, and multiple trading venues defined by differing market microstructures. We solve for the respective traders' demands in each market, and we provide conditions for participating (by the naive traders) and nonparticipating equilibria. We also characterize equilibrium asset prices in each market. Section 4 characterizes the equilibrium, and focuses on the listing decisions of firms. We demonstrate how firm characteristics, trader characteristics, and the cost of listing affect where firms list and their cost of capital. Section 5 returns to the role played by microstructure, and in, particular, considers listing standards and the role of market rules and trading practices. Section 6 concludes by discussing more broadly the effects of microstructure and regulation on firms' and investors' decisions to participate in equity markets.

[8] Indeed, Paiella [2006] notes that among households surveyed in the U.S. Consumer Expenditure Survey over the years 1982-1995 more than two-thirds held neither stocks nor bonds.

[9] Researchers have proposed a variety of explanations for non-participation in markets, including incomplete information (see Merton [1987]), a lack of trust (Guiso, Sapienza, and Zingales [2005]), and a variety of behavioral causes (see Barberis and Thaler [2000] for a review of the behavioral literature on this topic). Analyses linking nonparticipation to ambiguity are given by Cao et al [2005], Easley and O'Hara [2004], and Dow and Werlang [1992]. Guiso, Sapienza, and Zingales [2005] provide an interesting analysis showing empirically that trust in stock markets, which they argue is not related to ambiguity aversion, affects participation. What engenders trust in their model is not specified, but it seems sensible that perceptions of greater market integrity, which are one outcome of our microstructure solutions, would alleviate also alleviate trust concerns and thereby induce participation.

2. Ambiguity and Investor Behavior

Many households hold portfolios of assets that are inconsistent with expected utility maximization using correct expectations about payoffs. Campbell in his 2006 Presidential Address to the American Finance Association provides compelling evidence from various sources that a substantial fraction of households do not participate in equity markets and that many of those who do participate do not properly diversify their portfolios. There are several possible explanations for these failures to act as standard models imply. Some households could simply be making errors, some may be acting according to preferences or decision rules that are different from those we normally consider, some may have incorrect expectations, and some may be inexperienced and perhaps learn over time to improve their performance. Undoubtedly, a mixture of these and other stories are appropriate. In this paper, we model asset markets in which the behavior of some investors is consistent with objective expected utility maximizing behavior and the behavior of others is not.

Some of our investors know the payoff distribution for each asset. This rational expectations assumption is a strong, but standard, assumption. The other investors are aware of all assets but they do not act as if there is single payoff distribution for each asset. Instead they act as if there is a set of payoff distributions for each asset and they are unable or unwilling to place a prior on this set. The payoff distributions in this set reflect the uncertainty that some investors have about how the stock market works. These investors act as if they believe that both good and bad payoff distributions are possible, but they simply don't have enough experience to know which distribution is correct or to place a prior on the set of conceivable payoff distributions. These investors are naïve or ambiguity averse investors.

The famous Ellsberg Paradox provides experimental evidence that some, but not all, individuals do not act as if they have a prior. In a simple version of the Ellsberg experiment an individual is given an opportunity to bet on the draw of a ball from one of two urns. Urn one has 50 red and 50 black balls. Urn two has 100 balls which are an unspecified mix of red balls and black balls. First, subjects are offered a choice between two gambles: $1 if the ball drawn from urn one is red and nothing if it is black or $1 if the ball drawn from urn two is red and nothing if it is black. Many subjects chose the first gamble. Thus, if they have a prior on urn two the predicted probability of red in urn two is less than 0.5. Next, subjects are offered a choice between two new gambles: $1 if the ball drawn from urn one is black and nothing if it is red or $1 if the ball drawn from urn two is black and nothing if it is red. Many subjects again chose the first gamble. Thus, if they have a prior on urn two the predicted probability of black in urn two is less than 0.5. This cannot be, so they do not act as if they have only one prior on urn two.

This Ellsberg Paradox led Gilboa and Schmeidler [1989] to weaken the standard expected utility axioms in order to produce a decision theory consistent with the behavior observed by Ellsberg.[10] Their approach yields a Bernoulli utility function defined over payoffs but rather than a single prior it yields a set of priors. The axioms also imply that the decision maker evaluates any act according to the minimum expected utility it yields. In the Ellsberg framework this model implies that the individual acts as if he has a set of priors for urn two which includes a prior in which the probability of red is less than 0.5 and a prior in which the probability of black is less than 0.5. Since he acts as if evaluates each act according to its minimum expected utility, he will never chose urn 2 as in his pessimistic view it will be unlikely to pay off.

[10] Knight [1921] originally developed the notion of individuals making a distinction between known odds and uncertain or ambiguous odds. This distinction was noted by Savage [1954], but in his model of subjective expected utility it plays no role. The standard model of asset pricing is based on Savage's foundation for expected utility maximization. The distinction between Knightian uncertainty, now known as ambiguity, and risk has seen resurgence due to the work of Schmeidler [1989], Gilboa and Schmeidler [1989], and Dow and Werlang [1994].

The Gilboa and Schmeidler model has been generalized to allow for the possibility that the decision maker is not so pessimistic as to select an act that maximizes the minimum expected utility. Two recent papers by Ghirardato, Maccheroni and Marinacci (2004) and Klibanoff, Marinacci and Mukerji (2004) provide alternative approaches to separating ambiguity and the decision maker's attitude toward ambiguity. We follow the Gilboa and Schmeidler model to illustrate our ideas, but the results could be easily modified using alternative models of ambiguity aversion.

There are, at least, two other reasonable ways to view the decision problem faced by our naive decision makers. First, they could be thought of as choosing robust portfolios. That is, they could search for portfolios that are robust to their uncertainty about the correct model for payoffs. Hansen and Sargent (2000) follow this approach to evaluating macroeconomic models. Maenhout [2004] and Garlappi, Uppal, and Wang [2004] use a similar approach to consider asset pricing issues.[11] Second, they could be thought of as behavioral traders who either have biased beliefs or who do not maximize expected, or minimum expected, utility. We prefer the ambiguity aversion approach as it is based on preferences for stochastic consumption streams and axioms about those preferences.

3. The Model

We analyze an economy with I+1 assets. There is one risk free asset, money, which has a constant price of 1. There are I risky assets, denoted by i = 1,…,I. The future value of each risky asset is a random variable, and all investors know that these future values are independent and normally distributed. They do not necessarily know the mean or variance of these future values.

[11] Ambiguity issues in asset pricing have also been addressed by Dow and Werlang [1994], Longstaff, Liu, and Wang [2003], Cao, Wang, and Zhang [2004].

The set of possible means for the future value of asset i is $\{\overline{v}_1^i,...,\overline{v}_N^i\}$; the set of possible variances is $\{\sigma_1^i,...,\sigma_N^i\}$. All pairs of mean and variance are possible and we let $\Theta^i = \{\theta_1^i,...,\theta_n^i\}$, with $n = N^2$ elements, be the set of possible payoff parameters.[12]

There are J investors indexed by $j = 1,...,J$. All investors are ambiguity averse and they all have CARA utility for wealth, with risk aversion parameter set equal to 1:

$$u_j(w) = -\exp(-w). \qquad (1)$$

There are two types of investors in the economy, denoted S investors and U investors. Fraction $1-\mu$ of the investors are sophisticated or experienced investors (S) who have rational expectations about payoff parameters. Let $(\hat{v}^i, \hat{\sigma}^i)$ denote the true value of the mean payoff and variance for asset i. Since our sophisticated traders have rational expectations they know $(\hat{v}^i, \hat{\sigma}^i)$, and hence actually face no ambiguity about the payoff distribution.[13] Thus they act as if they are objective expected utility maximizers.

Fraction μ of the investors are naïve, or unsophisticated investors (U). Naïve investors also care about means and variances, but they differ from sophisticated investors in that they do not know the payoff parameters. Instead, they consider each normal distribution of payoffs, $N(\theta^i)$, as a possible payoff distribution. To make our analysis of the equilibrium interaction between S and U traders interesting, we assume that U investors consider as possible mean payoffs above and below $\hat{v}^i$ and variances above and below $\hat{\sigma}^i$. That is, the true parameter values are convex combinations of the extreme values considered possible by the U traders.

---

[12] As will become apparent only the minimum and maximum mean payoff and maximum variance affect decisions made by naive traders. So changes to the set Θ^i that leave these values unchanged have no affect on the market. In particular, Θ^i can be a continuum.

[13] Allowing S traders to have a common prior over Θ^i, rather than knowing the true values, complicates the analysis without adding to the intuition.

Following Gilboa and Schmeidler's (1989) axiomatic foundation for ambiguity aversion, we model investors as choosing a portfolio to maximize their minimum expected utility over the set of possible payoff distributions. Sophisticated investors only consider the normal distribution with parameters $(\hat{v}^i, \hat{\sigma}^i)$ to be possible, so they act as if they are objective expected utility maximizers. Naive investors consider all normal distributions with parameters in $\Theta^i = \{\theta_1^i, ..., \theta_n^i\}$ to be possible.

The per capita endowments of money and assets are $(\bar{m}, \bar{x}^1, ..., \bar{x}^I)$. The exact distribution of this per capita endowment over investors does not affect their demands for risky assets because of the CARA-Normal structure, so we do not specify it. We denote a typical investor's wealth by w. Where no confusion would occur, we will drop the investor index. The investor's budget constraint is

$$w = m + \sum_i p^i x^i \qquad (2)$$

where p^i is the price of asset i, m is the quantity of money and x^i is the quantity of risky asset i.

There are two stock markets, A and B, on which money and assets can be traded. The two markets differ from each other in terms of the services they provide to listing firms and investors. Market B is simply a trading platform, providing a venue in which buyers and sellers can transact. By contrast, Market A is an exchange that provides a range of certification services. One such service can be a listing function, whereby market A examines companies that apply to be listed on it and only agrees to list those that meet some minimum standards. For example, it may require that the company actually have assets, that it file audited statements about its payoffs, and that it meet a variety of corporate governance requirements. Additionally, market A may oversee clearing and settlement to insure that a trader who buys stock actually

receives it and that one who sells stock actually delivers it. Yet other dimensions could be that the exchange monitors the trading process to ensure that trading is non-manipulative, and sets trading rules and practices to ensure fair trading.

These certification services assure naive investors that some worst cases they might imagine for the mean or variance of the future value they receive do not occur. As the sophisticated investors already know the correct distribution of the future value, these services are not valuable to them. Note that we are not assuming here that the certification ensures that the stock is a good investment. The actual investment outcome for a stock can be very good or very bad; what the certification role does is rule out "blue sky" outcomes where either the company or the trade will fail to exist, or behaviors so egregious that the trader is destined to be exploited. Thus, naive investors interpret the certification activities of Market A as guaranteeing that the minimum mean future value of stock in firm i is v_*^i and that the maximum variance is σ_*^i. As a result, the perceived set of mean-variance parameters for the naïve investors changes to Θ_A^i, where in Θ_A^i the minimum mean future value is v_*^i and the maximum variance is σ_*^i.

Each firm must choose a market in which to list its stock. If firm i lists its stock on market B, it pays no cost and the future value that stock owners receive is v^i. If firm i lists its stock on market A, it pays a fee of c^i per share, which is deducted from the future value so that investors receive $v^i - c^i$. Note that we assume that listing a stock on one market versus another market changes the cash flow per share that investors actually receive only by the cost of listing per share. It does not affect pre-cost cash flows. In Section 4, we consider how the cost per share might vary from firm to firm, how this affects listing decisions, and how changes in the structure of costs affect asset prices and listing decisions.

We assume that each firm lists its stock on the market which provides the greatest equilibrium price for the stock. This seems a natural assumption for a new firm coming to market, but it is equally appropriate for a firm with existing traded equity because of its implications for the firm's cost of capital. In particular, the equilibrium stock price reflects the return investors demand to hold the stock, and these required returns in turn determine the firm's cost of capital. The higher the stock price, therefore, the lower is the firm's cost of capital, and so a firm's listing decision reflects this effect.

3.1 Asset Demands

We now turn to solving for investors' asset demands. Investors are allowed to go long or short in each asset. If the investor chooses portfolio $\left(m, x^1, ..., x^I\right)$ his random next period wealth will be

$$\tilde{w} = m + \sum_i \left(\tilde{v}^i - I^i c^i\right) x^i, \tag{3}$$

where I^i is 1 if firm i lists on market A and 0 otherwise.

For a sophisticated investor with CARA utility of wealth, the expected utility of this random wealth is a strictly increasing transformation of

$$\sum_i \left[(\hat{v}^i - I^i c - p^i) x^i - 1/2\, \hat{\sigma}^i (x^i)^2 \right] + w. \tag{4}$$

Calculation shows that the sophisticated investor's demand function for asset i is given by:

$$x_S^{i*}(p^i) = \frac{\hat{v}^i - I^i c^i - p^i}{\hat{\sigma}^i}. \tag{5}$$

A naive investor evaluates the expected utility of wealth for each parameter vector and chooses the portfolio that maximizes the minimum of these expected utilities.[14] In effect, the naive investor tries to avoid the worst case distributions of payoffs, and so chooses a portfolio that explicitly limits exposure to such adverse distributions. The expected utility of random wealth, given parameters $(\theta^i = (\overline{v}^i, \sigma^i))_{i=1}^I$, is a strictly increasing transformation of

$$\sum_i \left[(\overline{v}^i - I^i c^i - p^i) x^1 - 1/2\, \sigma^i (x^i)^2 \right] + w. \tag{6}$$

Thus, the naive investor's decision problem can be written as

$$\underset{(x^i)}{Max}\ \underset{(\theta^i)}{Min} \sum_i \left[(\overline{v}^i - I^i c^i - p^i) x^1 - 1/2\, \sigma^i (x^i)^2 \right] + w \tag{7}$$

where the minimum is taken over Θ_A^i if firm i lists on market A and over Θ^i if firm i lists on market B.

Examining the minimization problem reveals that for any portfolio the minimum occurs at the maximum possible variance for each asset. This variance is $\sigma_{\max}^i$ if firm i lists on market B or σ_*^i if firm i lists on market A. Whether the minimum occurs at the maximum or minimum mean payoff depends on whether the investor is long or short in the asset. The minimum occurs at the minimum mean payoff for asset i if the investor is long in asset i and at the maximum mean payoff if the investor is short in asset i. Denote these mean payoffs by $\overline{v}_{\min}^i$ and $\overline{v}_{\max}^i$, respectively, if firm i lists on market B and by $v_*^i - c^i$ and $\overline{v}_{\max}^i - c^i$, respectively, if firm i lists on market A. Calculation shows that the unsophisticated investor's demand function for asset i is

[14] As the correct mean and variance affect the demands of sophisticated investors these values will be reflected in equilibrium prices. We do not allow naïve investors to make inferences about these values from prices. That is, we do not treat the correct values as private information and analyze a rational expectations equilibrium. The level of sophistication that this would require of our naïve traders seems inconsistent with their naivety. We interpret our naïve traders as inexperienced; so how could they know enough to rationally infer private information from asset prices in markets in which they have not participated?

$$x_U^{i*}(p^i) = \begin{bmatrix} \frac{\overline{v}^i_{\min} - p^i}{\sigma^i_{\max}} \;\; if \;\; \overline{v}^i_{\min} > p^i, I^i = 0 \\ 0 \;\; if \;\; \overline{v}^i_{\min} \le p^i \le \overline{v}^i_{\max}, I^i = 0 \\ \frac{\overline{v}^i_{\max} - p^i}{\sigma^i_{\max}} \;\; if \;\; \overline{v}^i_{\max} < p^i, I^i = 0 \\ \frac{\overline{v}^i_* - c^i - p^i}{\sigma^i_*} \;\; if \;\; \overline{v}^i_* - c^i > p^i, I^i = 1 \\ 0 \;\; if \;\; \overline{v}^i_* - c^i \le p^i \le \overline{v}^i_{\max} - c^i, I^i = 1 \\ \frac{\overline{v}^i_{\max} - c^i - p^i}{\sigma^i_*} \;\; if \;\; \overline{v}^i_{\max} - c^i < p^i, I^i = 1 \end{bmatrix}. \qquad (8)$$

There are several properties of this demand function that will be important for our analysis. First, note that if the price of asset i is above the minimum possible mean net payoff and below the maximum possible mean net payoff, then the naïve investor will not participate in the market for asset i.[15] This occurs because a naïve investor is heavily influenced by the worst possible state, and what is worst depends on the investor's asset position. Second, note that the naive investor's decision about whether to hold the asset is independent of the set of variances he believes to be possible. All that matters for the participation decision is the price, the minimum mean net payoff and the maximum mean net payoff. If the naive investor decides to hold the asset, then variance matters, just as it does for the sophisticated investor. But note that only the maximum possible variance affects the quantity to be held by a naïve investor.

3.2 Equilibrium

In equilibrium two conditions must be satisfied. First, the per capita demand for each asset must equal its per capita supply. Equating the demands from equations (5) and (8) to this supply then yields for each asset i:

$$\mu x_U^{i*}(p^i) + (1-\mu) x_S^{i*}(p^i) = \overline{x}^i . \qquad (9)$$

[15] Here by not participating we mean that his final asset position will be zero. This interpretation is most natural if ambiguity averse investors do not initially hold the risky asset.

Second, each asset must be listed on the market which yields the greatest equilibrium price for the asset.

To construct the equilibrium, we determine the market clearing price for each asset if it is listed on market A and if it is listed on market B. Denote these prices by p_A and p_B, respectively. Because these demands are complex, the equilibrium may also be complex. In particular, depending on the parameters of the economy, there are two possible types of solutions to the market clearing equation.

Consider market clearing for stocks listed on market B. First, if at a price between $\overline{v}^i_{\min}$ and $\overline{v}^i_{\max}$ the sophisticated investors are willing to hold the entire supply of the asset, then in equilibrium the naïve investors will not participate in the market. If only S investors participate in the market the market clearing price must be

$$\hat{p}^i_B = \hat{v}^i - \frac{\hat{\sigma}^i \overline{x}^i}{1-\mu} \tag{10}$$

Thus, $\hat{p}^i_B$ will be the market clearing price for asset i listed on market B if $\overline{v}^i_{\max} \geq \hat{p}^i_B \geq \overline{v}^i_{\min}$. Note that $\overline{v}^i_{\max} \geq \hat{p}^i_B$ as $\overline{v}^i_{\max} \geq \hat{v}^i \geq \hat{p}^i_B$, so the binding condition is $\hat{p}^i_B \geq \overline{v}^i_{\min}$.

Second, it is possible that both types of investors participate in the market for asset i. If we conjecture that both types of investors participate, then the market clearing price must be

$$p^{i*}_B = \frac{\mu\hat{\sigma}^i\overline{v}^i_{\min} + (1-\mu)\sigma^i_{\max}\hat{v}^i - \overline{x}^i\sigma^i_{\max}\hat{\sigma}^i}{\mu\hat{\sigma}^i + (1-\mu)\sigma^i_{\max}}. \tag{11}$$

This can be a market clearing price only if naïve investors are willing to participate, i.e. only if $p^{i*}_B < \overline{v}^i_{\min}$. Calculation shows that this constraint is met if and only if $p^{i*}_B < \overline{v}^i_{\min}$. In order to insure that the price is sensible (greater than zero) even if there are only naïve investors in the market, we assume that $\overline{v}^i_{\min} - \overline{x}^i\sigma^i_{\max} > 0$.

As the binding condition for a non-participation outcome on market B is $\hat{p}_B^i \geq \overline{v}_{\min}^i$, one and only one of these prices will prevail. Thus, there is a unique market clearing price on market B. This equilibrium is either one in which naïve investors do not participate, a Non-Participating Outcome, or one in which they do participate, a Participating Outcome.

The analysis for stocks listed on market A is symmetric. The only difference is that the cost c^i is deducted from payoffs, and minimum payoffs and maximum variances are drawn from Θ_A^i rather than Θ^i. So the non-participating price on market A is $\hat{p}_A^i = \hat{v}^i - c^i - \frac{\hat{\sigma}^i \overline{x}^i}{1-\mu}$ and the participating price on market A is

$$p_A^{i*} = \frac{\mu\hat{\sigma}^i(\overline{v}_*^i - c^i) + (1-\mu)\sigma_*^i(\hat{v}^i - c^i) - \overline{x}^i\sigma_*^i\hat{\sigma}^i}{\mu\hat{\sigma}^i + (1-\mu)\sigma_*^i} \tag{12}$$

These results are summarized in the proposition below.

Proposition 1: In each market there is a unique market clearing price for asset i:

A. If firm i is listed on market A. then the market clearing price, p_A^i, is either:

1. Non-Participating: If $\hat{p}_A^i = \hat{v}^i - c^i - \frac{\hat{\sigma}^i \overline{x}^i}{1-\mu} \geq \overline{v}_*^i - c^i$ then $\hat{p}_A^i$ is the market clearing price; or

2. Participating: If $\hat{p}_A^i = \hat{v}^i - c^i - \frac{\hat{\sigma}^i \overline{x}^i}{1-\mu} < \overline{v}_*^i - c^i$ then p_A^{i*} is the market clearing price.

B. If firm i is listed on market B, then the market clearing price, p_B^i, is either:

1. Non-Participating: If $\hat{p}_B^i = \hat{v}^i - \frac{\hat{\sigma}^i \overline{x}^i}{1-\mu} \geq \overline{v}_{\min}^i$ then $\hat{p}_B^i$ is the market clearing price; or

2. Participating: If $\hat{p}_B^i = \hat{v}^i - \frac{\hat{\sigma}^i \overline{x}^i}{1-\mu} < \overline{v}_{\min}^i$ then p_B^{i*} is the market clearing price.

A firm will list its stock where the price is highest. Thus, firm i chooses to list its stock on market A if $p_A^i \geq p_B^i$, otherwise the stock of firm i is listed on market B. Note that if firm i's stock would be traded in a non-participating equilibrium on market A, then if it was listed on market B it would also be in a non-participating equilibrium. However, since $\hat{p}_A^i < \hat{p}_B^i$ no firm would chose to list on market A if the outcome on market A was non-participating. So in equilibrium either the firm is listed on market A and naive investors participate, or it is listed on market B where both participation and non-participation are potential outcomes.

Proposition 2: The equilibrium price for stock i is:

1. $\hat{p}_B^i$ if $\hat{v}^i - \frac{\hat{\sigma}^i \bar{x}^i}{1-\mu} \geq \overline{v}_*^i$.

2. $Max\{p_A^{i*}, \hat{p}_B^i\}$ if $\overline{v}_*^i > \hat{v}^i - \frac{\hat{\sigma}^i \bar{x}^i}{1-\mu} \geq \overline{v}_{\min}^i$.

3. $Max\{p_A^{i*}, p_B^{i*}\}$ if $\overline{v}_{\min}^i > \hat{v}^i - \frac{\hat{\sigma}^i \bar{x}^i}{1-\mu}$.

In the three cases above, case 1 corresponds to a non-participating equilibrium in market B. In case 2, the firm can choose between a participating equilibrium on market A and a non-participating equilibrium on market B. In case 3, it can choose between participating equilibria in either market. The participating equilibrium price on market A can be factored as follows

$$p_A^{i*} = \frac{\mu\hat{\sigma}^i \overline{v}_*^i + (1-\mu)\sigma_*^i \hat{v}^i - \bar{x}^i \sigma_*^i \hat{\sigma}^i}{\mu\hat{\sigma}^i + (1-\mu)\sigma_*^i} - c^i \equiv \tilde{p}_A^i - c^i \qquad (13)$$

where $\tilde{p}_A^i$ is the price that firm i's stock would sell for on market A if there was no fee. This means that in cases 2 and 3 a firm chooses to list on market A if and only if $\tilde{p}_A^i - p_B^i > c^i$. Since $\overline{v}_*^i \geq \overline{v}_{\min}^i$ and $\sigma_*^i \leq \sigma_{\max}^i$, we clearly have $\tilde{p}_A^i \geq p_B^i$. Thus, whether firm i selects market A over

market B depends on the economically reasonable calculation of whether the costs (c^i) exceed the benefits (the price increase before deducting the fee).

4. Characterization of Equilibrium

We now turn to understanding how firm, trader, and cost characteristics affect where a firm's stock will trade. As demonstrated above, the microstructure of the exchange can result in different stock prices for the firm, and consequently affect the resulting cost of capital for the firm. This attaches an importance to the listing decision for firms, investors and exchanges alike.

4.1 Payoff ambiguity and the listing decision

A simple measure of the ambiguity perceived by naïve investors is the difference between the beliefs of sophisticated investors regarding payoffs in this firm, and the corresponding beliefs of the naïve investors. These beliefs can differ in two relevant dimensions: mean and variance. Recall that the participation decision for naïve investors depends only on the price and $\overline{v}^i_{\min}$, while the decision of sophisticated investors to go long or short depends only on the price and $\hat{v}^i$. Although ambiguity about variance does not affect the participation decision by naïve traders, $\sigma^i_{\max}$ does affect the amount of the risky asset they chose to hold if they, in fact, participate. So ambiguity about variance can also affect where firms chose to list. We discuss the effects of these variables separately.

We first consider a case where the difference in perceived mean payoffs ($\hat{v}^i - \overline{v}^i_{\min}$) is large. Relative to sophisticated investors, naïve investors find this a very unappealing stock, and

so, should the firm trade on Market B, only sophisticated investors will hold the stock and a non-participating equilibrium will arise.

Would such firms instead opt to list on Market A? If the ambiguity about the mean return is large enough, the answer is no. If the ambiguity is high, even the certification services of market A may not be sufficient to induce naïve investors to hold the stock. For these firms, the market clearing price when the stock is held only by sophisticated investors is above the minimum mean payoff that unsophisticated investors believe Market A can provide. Thus, the only equilibrium in Market A is a non-participating one, which is also the equilibrium obtaining in Market B. But with no listing fee in Market B, it is optimal for the firm to choose the less expensive non-participating equilibrium and list on Market B.

Now consider the opposite case where the perceived ambiguity in mean payoffs is small. For these firms, naïve investors' beliefs about mean payoffs are very close to the beliefs of sophisticated traders, and so their participation decisions may also be very similar. For small enough ambiguity, it may be the case that naïve investors will opt to participate even if the stock trades on Market B. It is easy to demonstrate that should a participating equilibrium prevail in Market B, it will also prevail in Market A. But again, Market B is cheaper than Market A, so for firms with very little ambiguity about mean payoffs, Market B is the preferred venue.

This outcome need not arise for firms in the middle, those for whom ambiguity about means is not too large and not too small. These firms get a boost in share price from Market A's guarantees which may be large enough to compensate for the cost of listing on A. A necessary condition for this to occur is that Market A's guarantees induce the naïve to participate, whereas they would not do so if the stock trades on Market B. Note, however, that participation alone is not sufficient to ensure the supremacy of Market A. Because Market A charges firms to list, it

can be the case that the stock price in Market B's non-participating equilibrium is higher than it is in Market A's participating equilibrium, and the firm chooses market B. These effects can be illustrated by a simple example.

Example 1: Suppose that there is no ambiguity about variance, and that the effect of listing on market A is to increase the minimum mean payoff such that $\overline{v}_*^i = \overline{v}_{\min}^i + \alpha(\hat{v}^i - \overline{v}_{\min}^i), 0 < \alpha < 1$. That is, α measures the effectiveness of the certification role on market A. In this case, the equilibrium price of stock i as a function of the minimum mean payoff perceived by unsophisticated investors is described by Figure 1.

INSERT FIGURE 1

Firms with very low $\overline{v}_{\min}^i$ will be traded on market B and will be held only by sophisticated investors. Firms with intermediate $\overline{v}_{\min}^i$ will be listed on market A and will be held by both types of investors. Firms with high $\overline{v}_{\min}^i$ will be traded on market B and will be held by both types of investors.

Although ambiguity about variance does not affect the participation decision it does affect the amount that naive investors choose to hold, so it, too, affects the listing decision. Its effects are similar to those of ambiguity about means. To isolate the effects of variance ambiguity, we consider the case in which there is no ambiguity about means. In this case, there will be a participating equilibrium on either market. Naïve investors perceive a lower variance if the firm lists on A and so they demand more of the asset at any given price if the firm is listed on A than they would if the firm was listed on B. Thus, whether the firm lists on market A, and pays the listing fee for A, or trades on market B, and pays no fee, depends on the price increase

net of fees that A offers. If there is very little ambiguity about variance ($\sigma^i_{\max} - \hat{\sigma}^i$ is small), then there is little benefit to listing on A and the firm will trade on B. For firms with greater ambiguity about variance, the benefit of listing on market A increases, and as long as the cost of listing on A is not too large, these firms will choose to list on A. Finally, for firms with very large ambiguity about variance, the benefit of listing on market A may again be small as naïve investors will hold very little of the asset in any case. So these firms may chose to trade on B. These effects are illustrated in the following example.

Example 2: Suppose that there is no ambiguity about means, and that the effect of listing on market A is to decrease the maximum variance according to $\sigma^i_* = \sigma^i_{\max} - \alpha(\sigma^i_{\max} - \hat{\sigma}^i), 0 < \alpha < 1$. That is, as in the previous example, α measures the effectiveness of the certification role on market A. Figure 2 provides an example of the equilibrium price of stock i as a function of the maximum variance perceived by unsophisticated investors.

INSERT FIGURE 2

Firms with very low $\sigma^i_{\max}$ will be traded on market B, firms with intermediate $\sigma^i_{\max}$ will list on A and firms with very high $\sigma^i_{\max}$ will be traded on market B.

Overall, our analysis predicts that firms will sort out between markets in a systematic way. Firms with either very little or a lot of ambiguity about mean payoffs or the variance of payoffs will opt for the trading venue with no certification, but lower costs. Firms with moderate ambiguity about means or variances will benefit from paying the listing fees to an exchange in return for the certification services the exchange provides.

4.2. Trader populations and listing decisions

Our analysis above shows that firm characteristics will influence equilibrium listing decisions. We now consider a second factor that could affect the equilibrium, the composition of the trader population. In our model, fraction μ of traders are unsophisticated or naïve traders, while 1-μ are sophisticated traders. How does the fraction of naïve investors affect listing decisions?

Suppose we first consider the case where μ is small, or where all or nearly all investors are sophisticated. For such investors, the guarantees offered by Market A have no value, and these investors would be just as happy to trade on Market B. With few new investors induced to trade on Market A, there is little or no gain to the stock price, but the costs of listing remain. Consequently, no firm will pay the listing fee on Market A, and all firms will trade on Market B.

Alternatively, if all, or nearly all, investors are naïve (μ is near 1), then, if the stock is to be traded at all, equilibrium requires a share price low enough to attract naïve investors into the market. Firms will list on market A if the increase in minimum mean payoff that A offers to investors is larger than the cost of listing on A. Otherwise, they will trade on market B. Note, however, that if there are few sophisticated investors then the cost of capital the firm faces may be extremely high. We return to this issue later in the paper.

For intermediate populations of naïve traders, the listing decision will depend upon the relative costs and benefits that arise in each market. The greater the preponderance of naïve traders, the more likely it is that exchanges will predominate. The greater the predominance of sophisticated investors, the more likely it is that alternative markets will prevail.

Example 3: Suppose there is no ambiguity about variance ($\bar{\sigma}^i_{\max} = \hat{\sigma}^i = \sigma^i_* = \bar{\sigma}^i$) and that the certification provided by market A is price increasing when there are only naïve traders

($\overline{v}_*^i - c^i > \overline{v}_{\min}^i$). Figure 3 shows the resulting relationship between stock prices and trader populations.

INSERT FIGURE 3

We see that if there are not too many naïve traders ($\mu < \mu^*$) the equilibrium on market A would be non-participating, and so market B would also be in a non-participating equilibrium. Thus, for these low values of μ the firm trades on market B as paying market A generates no benefit. As we increase the fraction of naïve traders, the equilibrium on B eventually switches to a participating equilibrium. At this point the equilibrium on market A would also be participating, but the cost of listing on A is greater than the small price increase that switching to market A would yield. Thus, market B continues to dominate. Once we increase the fraction of naïve traders to μ^* the firm switches to market A. At this point, the price increase that A offers is large enough to overcome the listing cost as the large fraction of naïve traders depresses the price that would be received on market B. For even larger values of μ market A clearly remains dominant. [16]

4.3 Fees and the Listing Decision

We have modeled listing fees as a per share charge the company pays which is then deducted from the per share payoffs provided to investors. Our model allows this charge to vary firm by firm, and, in fact these charges do vary. Current market practices involve an up front listing fee and a continuing fee. The continuing fee schedule is increasing in size, but it is capped, resulting in larger companies paying disproportionately smaller fees per share. Declining listing fees per share make it more likely that large firms will list on Market A and

[16] It is also possible to have the switch to market A occur for values of μ low enough so that a participating equilibrium on market B would never be chosen.

small firms on will trade Market B. Such an outcome is consistent with listing patterns in the U.S., where the median size firm on the OTC or Pink Sheets is several orders of magnitude smaller than firms listed on the exchanges or the Nasdaq.

The cost c^i of listing on an exchange can also be interpreted to include costs borne by the listed company that are required for listing but which do not accrue to the exchange itself. The Sarbanes-Oxley regulations are one example of such a cost.[17] Sarbanes requires firms listing on U.S. stock exchanges to meet a number of costly requirements, the most onerous of which involve documenting and maintaining "an adequate, internal control structure and procedures for financial reporting" (Section 404). This regulation increased compliance costs for all listed firms, but costs increased dramatically more for smaller firms than for larger firms.[18] By some estimates, for medium sized companies the cost of being public has risen 223% since 2002 when Sarbanes first took effect.[19]

A natural structure to use to model these overall listing costs is as a fixed cost C plus an exchange-based cost per share (which we represent in shares per capita) of c. The listing cost per share in our analysis is then given by $c^i = C/\bar{x}^i + c$. Interpreting the effect of Sarbanes-Oxley on listing costs as an increase in C, we now ask how does this change affect a firm's listing decision?

INSERT FIGURE 4

[17] Another example are costs connected with SEC disclosure regulation. Bushee and Leuz [2005] provide an insightful analysis of the impact of a 1994 regulatory change requiring firms on the OTCBB to comply with disclosure requirements. They document that the imposition of such disclosure requirements significantly increased costs for smaller firms, and forced many of them to leave the OTCBB for the unregulated Pink Sheets.

[18] For estimates of these implementation costs see "Sarbanes-Oxley Act: Consideration of Key Principles Needed in Addressing Implementation for Smaller Public Companies," General Accounting Office, GAO – 06-361, April 2006. See also "Sarbanes-Oxley: A price worth paying?", The Economist, May 19, 2005, where compliance costs are estimated to be 2.5% of revenues for companies with revenues of $100 million or less.

[19] Estimates from Foley and Lardner as cited in "Sarbanes-Oxley not NYSE for New York", http://eddriscoll.com.

We first address how share prices and listing decisions are affected by the new regulations under the assumption that the regulations do not change the beliefs of either sophisticated or naïve investors. As shown in Figure 4, increasing the fixed cost of regulation causes the marginal firms, those in the interval $[\overline{x}_0, \overline{x}_1]$ to chose to be unlisted rather than to list on an exchange. Thus, one empirical implication of our analysis is that smaller firms that previously were listed will opt to leave the public markets. Empirical evidence supporting this is provided by SEC deregistration data, which show an increase from 143 firms deregistering in 2001 to 245 firms in 2004.[20]

An interesting corollary to this listing result is to consider the related issue of international listing decisions. Because the Sarbanes-Oxley costs apply only to listing in U.S. markets, we could interpret our cost function as being C>0 for listing on U.S. exchanges, and C=0 for listing on an international exchange. It is easy to see that *ceterus paribus*, the imposition of Sarbanes reduced the net benefits of listing on a U.S. exchange relative to a foreign exchange. Again, empirical evidence supporting this effect is provided by new international listing data, which show that in 2005 the NYSE and Nasdaq together had only 28 new international listings, compared with 50 new international listings on the two largest European exchanges.

A second empirical prediction of our model is that increasing the fixed cost of listing also causes the prices of all listed firms to fall as it lowers the cash flow per share accruing to shareholders. Of course, this analysis assumes that the regulations which are responsible for increasing costs of listed firms do not change the beliefs of either naïve or sophisticated investors. If, instead, they result in increased actual cash flow or a reduction in ambiguity for naïve investors, then this effect in isolation would cause prices of listed firms to increase. If this

[20] Virtually all of these deregistrations are small firms, a result the GAO [2006] study attributes to Sarbanes-Oxley compliance costs.

effect dominates the cost effect, then in equilibrium more firms would chose to list and prices would rise.

Zhang [2005] provides evidence against such ameliorative effects. Using an event study methodology, Zhang estimates that the loss in market value connected with the Sarbanes-Oxley regulation was on the order of $1.4 trillion dollars. The limitations of event studies require caution in interpreting this figure, but nonetheless the data do suggest that the net costs on firm value of Sarbanes-Oxley exceed the benefits.

4.4 Endogenous Listing Fees

Our analysis assumes that fees are exogenously set at c^i. Endogenizing listing fees introduces a number of interesting dimensions to the analysis. In the simplest framework where exchanges compete only for listing revenue, listing fees should equal the cost of providing certification services. To the extent that such services involve a large fixed cost, then larger markets can offer services more cheaply, and listings would be expected to consolidate only on large venues. Such an outcome is descriptive of U.S. markets, where now only the NASDAQ, the NYSE, and the American Stock Exchange actively list stocks.[21]

A more realistic scenario is to recognize that an exchange is actually a multi-product firm, producing revenues from both listings and trading. Foucault and Parlour [2004] analyze decision-making of a vertically integrated exchange that competes for IPO listing by choosing both the level of its listing fees and its trading fees (via its choice of trading technologies). These authors argue that entrepreneurs' listing decisions will depend upon both listing fees and trading costs, and they demonstrate that exchanges may choose different trading technologies to relax

[21] An interesting development in equity markets is the entrance of ArcaEx, the electronic trading platform recently merged into the New York Stock Exchange, into the listings business. Much of their focus appears to be on dual listing stocks listed elsewhere as their listing requirements note that "If the issuer was approved for listing [on another exchange] within the last twelve months, ArcaEx will accept a copy of the application and all supporting materials." For more information on AracEx listing requirements see www.arcaex.com

competition for listings.[22] An interesting result in this model is that low trading cost exchanges can charge higher listing fees.

Our model does not include technology, but it does have implications for the trading costs facing investors. Listing services are valuable to firms in our model because the enhanced participation they engender raises a company's stock price. With more investors holding the stock, trading volume would also be expected to increase, as there are more traders who can be subject to liquidity shocks and the like. Because trading costs are generally scale-driven, the greater is the trading volume the lower is the cost, and so participation would endogenously influence trading costs. Showing these effects explicitly in our analysis would require adding additional trading periods, and explicit liquidity shocks affecting traders, but the overall impact would be to increase the advantages accruing to exchanges better able to induce participation via their certification process. Thus, the trade-off between listing fees and trading costs demonstrated by Foucault and Parlour [2004] is even more likely to arise when participation effects are considered.

Markets may differ with respect to how well they can perform this certification function, providing the potential for monopoly rents to exchanges. The listing fees of the NYSE are substantially above those of the Nasdaq, reflecting a "premium" that firms pay to list on a higher quality market. Whether such listing fee differences reflect actual market quality differences, however, is increasingly coming into question, engendering substantial competition between exchanges for listings.[23] Indeed, the Deutsche Borse has recently introduced zero listing fees for international firms listing there, and the Nasdaq has offered a similar free listing to any of the

[22] Vertical integration is most applicable if where a stock trades is dictated by where a stock lists. While this was traditionally the case in equity markets, the rise of alternative trading venues, combined with increased competition between exchanges, has severed this link for many stocks. We discuss these issues more fully later in this section, but we note that if listing and trading are separable then the listing fee decision need not be linked to trading costs.
[23] See Parlour and Seppi [2003] for an interesting analysis of competition between trading venues

Dow index stocks. What is very real for exchanges is how important listing fees are as a revenue source. For the NYSE, for example, listing fee revenue constitutes more than a third of the exchange's total revenues, a figure substantially higher than the 13% of revenues listing fees averaged across exchanges world-wide in 2004.[24]

5. The Role of Microstructure

In our model, specific features of the microstructure can reduce the ambiguity in a market and thereby influence the participation decision of traders. In this section, we illustrate these effects by considering the implications of our model for listing standards and the role of trading systems, rules, and practices. Our particular focus is to delineate the role that specific features of the microstructure play in affecting market and trader behavior. Our analysis suggests that exchanges may compete for naive investors via the structure of their trading systems and the design of their market rules and practices.

5.1. Listing standards

The exchange in our model provides certification services that allay the fears of naïve investors regarding aspects of the firm and its trading. An interesting feature of these services is that they need only deal with downside outcomes; ambiguity averse investors are not concerned with unlikely favorable outcomes. Listing standards are one means to achieve this purpose. Listing standards generally specify that firms must have a certain number of outstanding shares, must meet financial disclosure and governance requirements, must not be bankrupt or delinquent in SEC reporting requirements, must have audited financial statements, and must observe

[24] For data on listing fees and exchange revenues, see "World Federation of Exchanges Cost and Revenue Survey 2004", World Federation of Exchanges, August 2005, pages 21-22.

corporate formalities such as annual meetings and the like. Such standards ensure that a functioning corporation exists and that there will be sufficient shares to ensure an orderly market.

What listing standards do not ensure, however, is that the firm is a good investment, or even necessarily a good company. Neither the NYSE nor the Nasdaq investigate firms as to their business plans or operations; they do not collect data on operating efficiency or performance; and there is no requirement for continued listing that firms make profits or provide adequate, or even positive, payoffs for their investors. Thus, unlike rating agencies such as S&P or financial analysts who explicitly evaluate firm quality, stock exchange listing requirements only certify that firms are on-going concerns.

Such a certification role, as opposed to a signaling role, is exactly predicted by our ambiguity-based analysis. Listing in our model does not change the objective risk-payoff characteristics of the firm; the beliefs of sophisticated investors, who have such beliefs, are not changed when the firm lists. Consequently, the long-run performance of firms as measured by accounting data should not be directly affected by where the firm lists. However, because the beliefs of the naive investors change, the firm's stock price is affected by their increased participation. Thus, an immediate empirical implication of our model is that listing should increase the number of shareholders in the stock. Perhaps more importantly, this increased participation should also be accompanied by a positive price change.

There are a large number of studies that show strong positive price effects for firms moving from the Nasdaq or Amex markets to the NYSE (see, for example, Christie and Huang [1993] and Kadlec and McConnell [1994]), and large negative effects for firms delisting from the NYSE and moving to the Pink Sheets (see Macey, O'Hara, and Pompilio [2005]). Foerster and Karolyi [1999] find both an increase in firm value and an increase in the number of

shareholders for non-U.S. firms cross-listing in the U.S., a finding they attribute to increased investor recognition. As we argue here, however, such effects are also consistent with an ambiguity-reducing role for exchanges.

An alternative view of stock exchanges is that they do perform a signaling function, allowing investors to sort out the good stocks from the bad stocks. Chemmaneur and Fulghieri (CF) [2005] investigate such a role in a model analyzing a new firms' choice between exchanges to list their equity. Their analysis focuses on asymmetric information between firms and investors, where some investors can gather information cheaply and other investors face higher costs. Exchanges in this model do not actually set prices as the price is set by the entrepreneur. What exchanges do is provide an investor base (investors in their model are assigned to a specific exchange), and a signal to investors of firm quality. An interesting implication of this model is that firms listing on "higher quality" exchanges should have higher payoffs.

Our model does not include asymmetric information, and so we cannot address many of the interesting issues considered by CF. We note, however, that the signaling role envisioned there is more akin to the role played by underwriters than by exchanges. In particular, underwriters have a due diligence requirement to investigate firms, while as noted above, exchanges do little beyond enforcing general requirements across all listed firms. Whether this is informative to investors as to the firm's prospects is an empirical question, but to our knowledge it has not been shown that listing standards are actually predictive of future firm performance.[25] Nonetheless, it seems sensible that listing activities address both ambiguity issues and asymmetric information issues, providing a double importance to the role of microstructure.

[25] An interesting paper by Doidge, Karolyi and Stulz [2004], however, finds that non-US firms cross-listed in the U.S. have higher valuations than do non-cross-listed stocks. They suggest that such an effect may be due to reduced agency problems in U.S. markets.

5.2. Market Design, Rules and Practices

In our model, exchanges change beliefs of naive investors by assuring these investors that some worst cases they imagined for the mean or variance of the payoff do not occur. One such concern may arise with respect to clearing and settlement of the trade, as an investor may fear that the counterparty simply takes his money and the investor gets nothing in return. Margin rules are one mechanism exchanges use to deal with counterparty default, but all trading platforms face this problem and they solve it in a variety of ways. For example, Ebay initiated a "PayPal buyer protection plan" to reduce uncertainty about settlement on its trading platform. EBS, an FX trading platform, uses a complex pre-screening system to limit which traders can trade with each other.

Another concern of naïve investors may be that they can be taken advantage of by market professionals. For example, traders may fear that brokers will execute their trades only when it is in the interest of the broker, and not in the interest of the customer, or that brokers will trade in advance of the customer order, thereby removing or reducing the investor's gain on a trade. Similarly, traders may fear that specialists will set bid and ask prices to exploit a trader's desire to buy or sell rather than quote prices that reflect an asset's true value. Other concerns may relate to dealers either being unwilling to trade with customers when they wish to sell, or alternatively coercing traders to buy stocks which are destined to be poor investments.

Exchanges and trading venues deal with these issues in a variety of ways. Virtually all equity markets and exchanges have a "Know your customer" rule that imposes a suitability requirement on exchange members and brokers. Suitability requires brokers to recommend only those investments suitable for the investor's objectives, rather than those that maximize the

broker's income.[26] Similarly, exchanges (and regulators) typically impose a duty of best execution on members to ensure that the customer trades at the best price available. Exchanges also generally forbid "front-running" by exchange members, thereby protecting the time priority of the investor's order. The NYSE has a variety of rules to curtail specialist behavior, including an "affirmative obligation" to act as a counterparty at a reasonable price whenever a customer wants to trade; a "public comes first" rule which precludes the specialist from disadvantaging a public order; and a price continuity rule which limits how much the specialist can change his quoted prices. A number of exchanges, such as the Deutsche Borse and Euronext, also require stocks to have designated market makers, who must make a quote for the stock in all market conditions. All of these trading rules work to reduce the ambiguity attached to "worst case" scenarios, and thus induce investors to participate in the market.

Naïve investors may also fear that they will be taken advantage of by other market players, particularly with respect to trading on new information. For example, traders may fear that company insiders will sell ahead of public news, leaving the naïve trader holding the now depreciated shares. Trading halts that preclude trading until events are publicly clarified can address these concerns.[27] A related concern is that sophisticated traders may respond to public news much more quickly than do naïve traders, resulting in naïve traders confronting dramatically lower prices before they can rebalance their positions. Limit moves, or bounds on how much prices can move in any day before trading is suspended, are one response to this

[26] For a discussion of suitability requirements and ambiguity see Easley and O'Hara [2005].
[27] Trading halts are also applied in futures and options markets when a price change in the futures market runs too far ahead of the underlying stock price index. The Tokyo Stock Exchange, for example, explains "to lessen investors concerns by providing them with a basis to make rational investment decisions, a temporary trading halt system was introduced in the futures and options markets" (see Fact Book, 2006, page 56).

problem. The Tokyo Stock Exchange, for example, sets daily price limits that generally limit price movements to approximately 10% from the previous day's closing price[28].

Yet another fear that investors may harbor is that the stock price could be manipulated by speculators, who then profit at the naïve investors expense. Exchanges invest heavily in stock watch and trade monitoring systems to preclude exactly such behaviors. Naïve investors may even fear that "animal spirits" or irrational herding will cause prices to fall so rapidly that the market can collapse; circuit breakers and price collars are trading practices that can address these concerns.

The examples given above illustrate the important role that trading rules and practices can play in ruling out aberrant outcomes that concern ambiguity averse investors.[29] A cursory review of an exchange rule book reveals myriad rules and requirements, some so arcane as to be rarely, if ever, actually binding in practice. Yet, such obscurity is perfectly consistent with the ambiguity-resolving role detailed above; ruling out potential outcomes, even those that have virtually no chance of actually ever occurring, is what reduces ambiguity and thereby induces participation. As a consequence, market design may play an important role not only in affecting risk and payoff, but uncertainty as well.

6. Conclusions

This paper has demonstrated the potential benefits to exchanges, investors and firms from reducing ambiguity. Ambiguity over how markets work or asset prices are formed can cause

[28] See Tokyo Stock Exchange Fact Book 2006, page 7-8.

[29] EBay presents an interesting example of the challenges connected with the integrity of items sold by sellers to buyers on their system. The incidence of counterfeit goods on EBay has increased dramatically, which, along with angry buyers, has also precipitated a law suit by Tiffany & Company accusing EBay of facilitating the trade of counterfeit goods. EBay argues that it is only an auction facilitator, and so under no obligation to ensure integrity. Our ambiguity-based analysis, however, suggests that uncertainty over product characteristics should induce non-participation, a undesirable outcome for any trading system. For more discussion, see "Seeing Fakes, Angry Traders Confront EBay," New York Times, January 29, 2006, pg. 1.

some traders to be overly influence by "worst case" outcomes, even when these outcomes have little objective possibility of occurring. This, in turn, can cause such naïve investors to opt not to participate in markets, a result detrimental to both markets and the economy alike. As we have demonstrated here, microstructure features can be used to reduce this ambiguity, and thereby induce greater participation in markets. Because traders will gravitate to markets where uncertainty is lower, microstructure can play an important role both in the competitiveness of markets and in the overall determination of risk premia.

While the participation-based issues we have addressed here are an important concern for large companies, they may be even more important for small companies. Large companies are often held by institutional investors, who surely are much better described as sophisticated investors. Moreover, large companies are often older, have greater public information, are followed by financial analysts, and have greater familiarity to consumers, all features that might be expected to reduce uncertainty for investors. This is not the case for many small firms. Institutions often eschew holding small companies, in part because of the difficulty of amassing (or trading out of) large positions. Moreover, even finding information on small firms can be difficult, limiting the number of investors who could be sophisticated. The active role played by private equity firms in financing small, fledgling firms is consistent with this difficulty in finding knowledgeable investors. Indeed, if ambiguity regarding a firm is too high, private equity may be the only recourse to obtain investment capital.

Small firms that do have public equity are often unable to meet the scale-related listing requirements of the exchanges, and so must trade in over-the-counter venues such as the Pink Sheets. Here the microstructure issues we have described take on particular relevance, as many

individual investors will simply not invest in a stock that is traded on the Pink Sheets.[30] Such reluctance is understandable for, as discussed in Easley and O'Hara [2005], a perplexing feature of U.S. securities market regulation is that listed firms face much more stringent regulations than unlisted firms, resulting in the least investor protection for these unlisted firms.[31]

Recently, the Pink Sheets have proposed changes to differentiate firms listed on the Pink Sheets into quality tiers. The "Premier QX" stocks will include companies large enough to be listed on a major exchange, with audited financial reports and annual shareholder meetings. Smaller companies with audited financials will be in the next tier, and all other stocks in the lowest tier.[32] Such changes are consistent with our analysis here, where we have argued that certifying firm quality to investors can induce participation if it lowers ambiguity enough. It remains to be seen whether the relatively modest changes proposed can accomplish this task.

Our analysis may also have particular relevance for issues connected with financial market development. A growing literature (see, for example, Bekaert, Harvey, and Lundblad [2001; 2005]) suggests that economic growth may be linked with financial market development, raising the issue of how to induce participation in a country's financial markets. Here the role of ambiguity seems particularly significant, as even sophisticated investors elsewhere may feel naïve when it comes to investing in unfamiliar settings. Microstructure can play a role by reducing this uncertainty. As we have argued, trading practices, trading procedures, and market

[30] Such views are reflected in the statement of Gerald Laporte, Securities and Exchange Commission, "A lot of people think of the Pink Sheets as a pejorative term. That's not good for the market. We need to clear up the Pink Sheets so that small companies have a trading platform that is more viable". See "Pink Sheets Aims for Respectability Under Ex-Trader", *Wall Street Journal*, Dec. 17, 2005.

[31] Legally, the Pink Sheets are not actually a stock exchange or a stock market, but rather a SIP, or securities information processor (see Macey, Pompilio, and O'Hara [2004] for discussion). As a SIP, firms trading on the Pink Sheets are not subject to many SEC requirements for public companies such as Sarbanes-Oxley requirements.

[32] Cromwell Colson, CEO of the Pink Sheets, noted "I am trying to wade in, pull the good ones out of the drudge, and let the drudge get drudgier". See op cit, *WSJ*, Dec. 17, 2005

rules all play a role in reducing potential "worst case" outcomes, and this may allow participation that otherwise would not occur.

A particular implication of our analysis is that countries (or markets) competing for investors need to place greater restrictions to rule out downside outcomes. An example of this approach is the "super listing standard" successfully employed by the Bolsa de Valores do Sao Paulo to attract listings and investors to Brazil.[33] Yet, stock exchanges alone may not be able to overcome the ambiguity facing investors due to uncertainties connected with a country's legal and regulatory system. Addressing ambiguity at this level may be even more important for inducing participation in emerging markets.

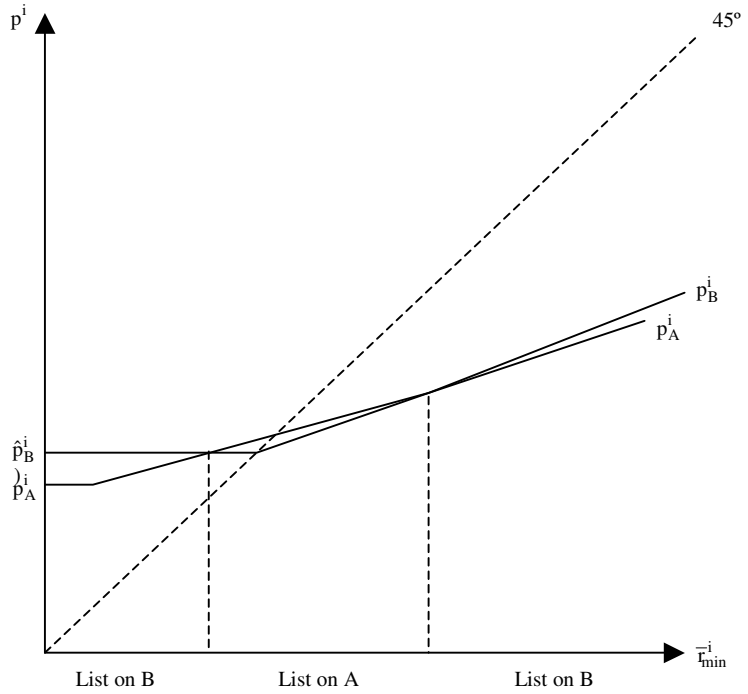
Finally, we note that a natural concern with our analysis is whether ambiguity, *per se*, is actually an important influence in actual markets. We believe that it is, reflecting our view that the complexity of markets places heavy demands on investing agents, resulting in oft-observed behaviors that are inconsistent with the predictions of more standard models. And we note that the disparity of participation and diversification across investor groups is consistent with the naïve-sophisticated investor divergence we have modeled here. Other authors, such as Guiso, Sapienza, and Zingales [2005] argue that participation may result from non-ambiguity aversion related behavioral causes such as "trust". Similarly, transaction costs combined with asymmetric information can also surely influence the ability of agents to access markets. Our own view accords a role to such causes, but we argue that there is a distinctive role played by ambiguity as well.

The debate over uncertainty, or ambiguity, has a long history in economics, and the resurgent interest in ambiguity is unlikely to resolve such a long-standing debate. What may

[33] Huddart, Hughes, and Brunnermeir [1999] provide an excellent analysis of the role of disclosure standards in affecting international cross-listing.

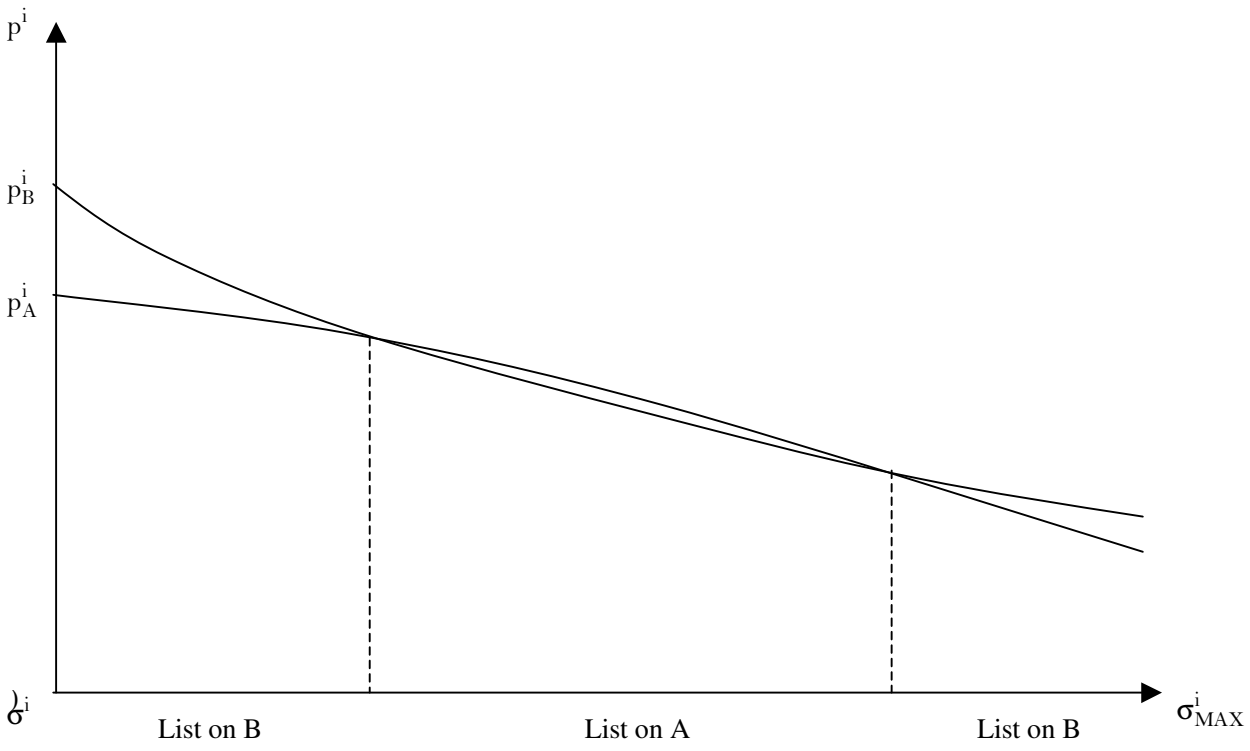
help decide the issue, however, is whether ambiguity-based analyses provide insights into market behaviors in new and meaningful ways. We hope our analysis provides a step in that direction.

Figure 1
Listing Decisions and Minimum Mean Payoffs



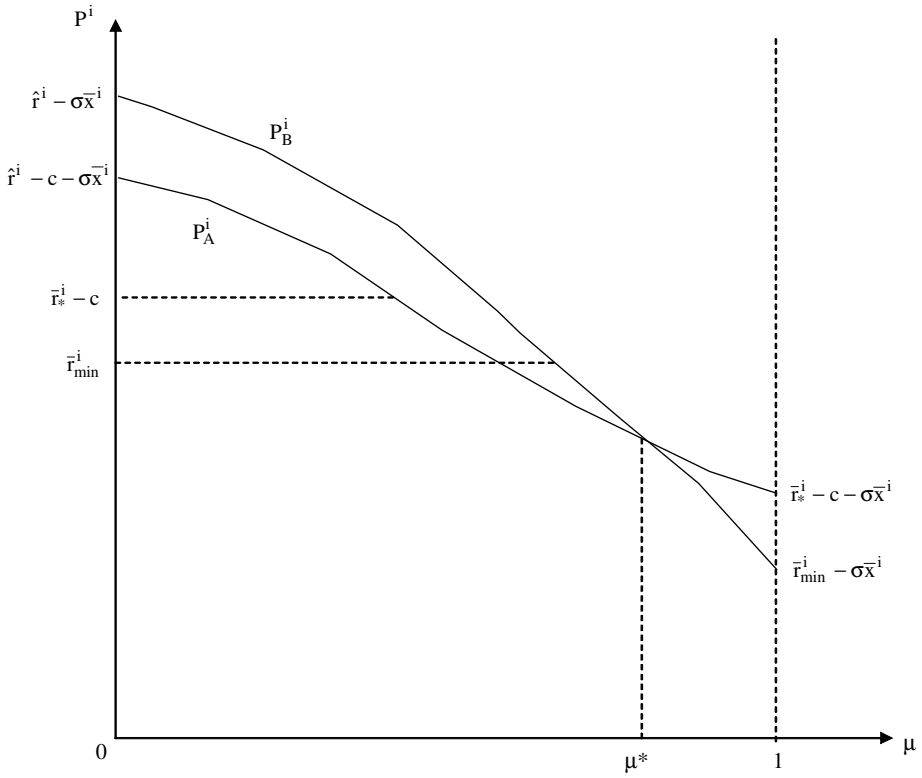
This figure shows how a firm's stock price, p, depends upon ambiguity averse investors' minimum mean payoff and the trading venue. Market A provides a certification service and charges a listing fee, whereas Market B provides no certification and charges no fee.

Figure 2
Listing Decisions and Maximum Variance



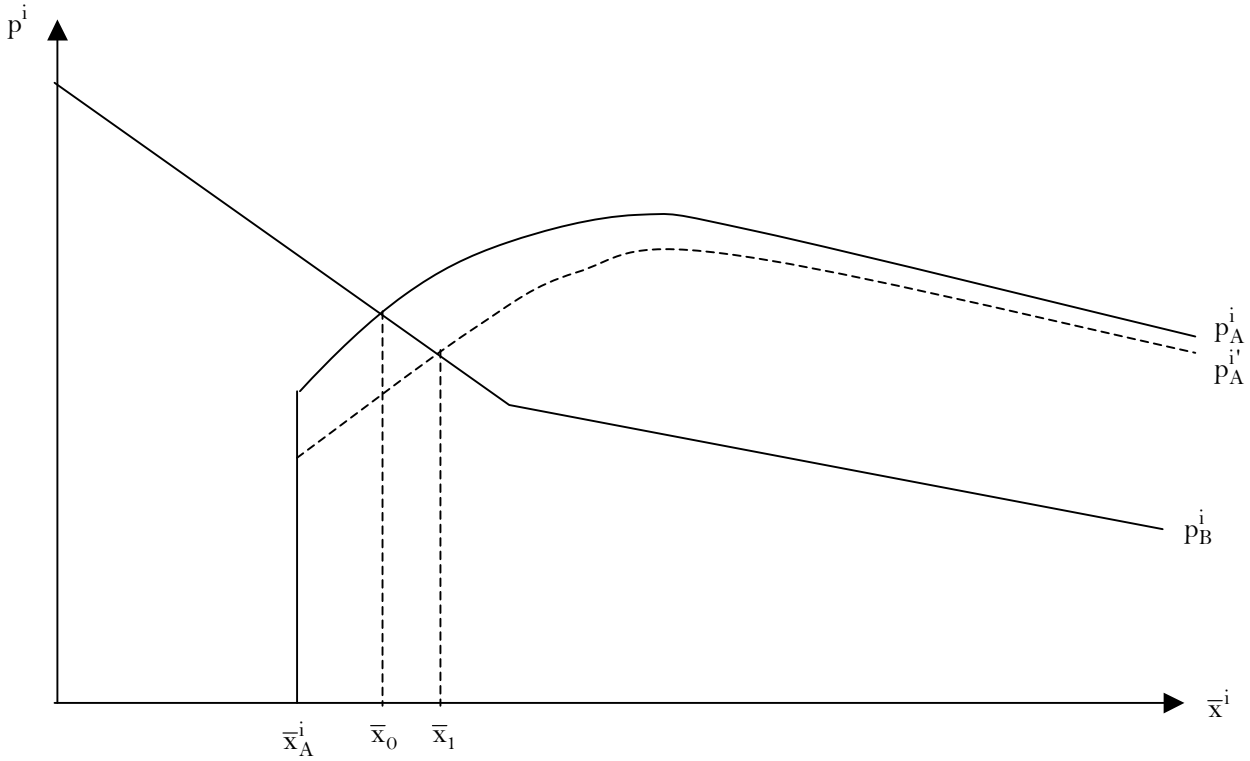
This figure illustrates the dependence of a firm's stock price on the maximum variance perceived by naïve investors.

Figure 3
Stock Prices and Trader Populations



This figures shows how changing the fraction of naïve investors, μ, affects a firms stock price when it lists on Market A (with certification services) and on Market B (without certification services.

Figure 4
Listing Decisions and Listing Costs



This figure illustrates the dependence of listing decisions on firm size for two levels of listing costs. Initially, firms with size below $\overline{x}_0$ trade on B and those above $\overline{x}_0$ list on A. If the fixed cost of listing increases, then prices on A fall (to $p_A^{i'}$) and firms in the integral $(\overline{x}_0, \overline{x}_1)$ would chose to trade on B rather than to list on A. [The graph illustrates the price on A only for firms of size $\overline{x}_A^i$ or larger. These firms would be in a participating equilibrium on A.]

References

Ahn, H.J., Cai, J., Hamao, Y. and M. Melvin, 2005, "Little Guys, Liquidity and Informational Efficiency of Price: Evidence from the Tokyo Stock Exchange on the Effects of Small Investor Participation", Working Paper, University of Southern California.

Barberis, N. and R. Thaler, 2003, "A Survey of Behavioral Finance," in *Handbook of the Economics of Finance*, M. Harris and R. Stultz, editors, Elsevier Science, North Holland, Amsterdam.

Basak, S. and D. Cuoco, 1998, "An equilibrium model with restricted stock market participation," *Review of Financial Studies*, 11, 309-341.

Bekaert, G., Harvey, C., and C. Lundblad, "Emerging Equity Markets and Economic Development," *Journal of Development Economics* 66, (2001): 465-504.

Bekaert, G., Harvey, C., and C. Lundblad," Does Financial Liberalization Spur Growth," *Journal of Financial Economics* 77, (2005): 3-56.

Brav, A., Constantinides, G. and C. Geczy, 2002, "Asset Pricing with Heterogeneous Consumers and Limited Participation," *Journal of Political Economy*, 110, 793-824.

Bushee, B., and C. Leuz, "Economic Consequences of SEC Disclosure Regulation: Evidence from the OTC Bulletin Board," *Journal of Accounting and Economics* (2005): 233-264

Campbell, J., 2006, "Presidential Address: Household Finance," *Journal of Finance*, *forthcoming*.

Cao, H., T. Wang, and H. H. Zhang, 2005, "Limited Market Participation and Asset Prices," *Review of Financial Studies*.

Chemmanur, T. J., and P. Fulghieri, 2003, "Competition and Co-operation Among Exchanges: A Theory of Cross Listing and Endogenous Listing," *Journal of Financial Economics, forthcoming*.

Chordia, T., R. Roll, and A. Subrahmanyam, 2000, "Commonality in Liquidity," *Journal of Financial Economics*, April.

Chordia, T., A. Sarkar, and A. Subrahmanyam, 2005, "An Economic Analysis of Stock and Bond Liquidity," *Review of Financial Studies*, Winter.

Christie, W. and R. Huang, 1993, "Market Structure and Liquidity: A Transactions data study of exchange listing," *Journal of Financial Intermediation*, 3, 300-326.

Doidge, C., G.A. Karolyi, and R. Stulz, 2004, "Why are Foreign Firms that list in the U.S. worth more?" *Journal of Financial Economics*.

Dow, J., and S. Werlang, 1992, "Ambiguity Aversion, Risk Aversion, and the Optimal Choice of Portfolio," *Econometrica*, 60, 197-204.

Easley, D., S. Hvidkjaer, and M. O'Hara, 2003, "Is Information Risk a Determinant of Asset Payoffs?" *Journal of Finance*.

Easley, D. and M. O'Hara, 2004, "Information and the Cost of Capital," *Journal of Finance*.

Easley, D. and M. O'Hara, 2005, "Regulation and Payoff: The Role of Ambiguity Aversion," Working Paper, Cornell University.

Ellsberg, D., 1961, "Risk, Ambiguity and the Savage Axioms," Quarterly Journal of Economics, 75, 643-669.

Foerster, S. R. and G. A. Karolyi, 1999, "The Effects of Market Segmentation and Investor Recognition on Asset Prices: Evidence from Foreign Stocks Listing in the United States," Journal of Finance, 54 (3).

Foucault, T., and C. Parlour, 2004, "Competition for Listings", *The Rand Journal of Economics*, 35 (2), 329-355.

Garlappi, L., Uppal, R. and T. Wang, 2004, "Portfolio Selection with Parameter and Model Uncertainty: A Multi-Prior Approach," *Review of Financial Studies*, forthcoming.

Gilboa, I. and D. Schmeidler, 1989, "Maximin Expected Utility Theory with Non-Unique Prior," *Journal of Mathematical Economics*, 18, 141-153.

Ghirardato, G., F. Maccheroni and M. Marinacci, 2004, "Differentiating Ambiguity and Ambiguity Attitude," *Journal of Economic Theory*, 118 (2004) 133-173.

Guiso, L., Sapienza, P., and L. Zingales, 2005, "Trusting the Stock Market," Working Paper, Harvard University.

Hansen, L.P. and T. J. Sargent, 2000, "Wanting Robustness in Macroeconomics," http://home.uchicago.edu/~lhansen/wanting.pdf

Huddart, S., J. Hughes, and M. Brunnermeir, 1999, "Disclosure requirements and stock exchange listing choice in an international context," *Journal of Accounting and Economics*, 26, 237-269.

Kadlec,G. and J. McConnell, 1994, "The effect of market segmentation and illiquidity on asset prices: Evidence from exchange listings," *Journal of Finance*, 49, 611-636.

Klibanoff, P., M. Marinacci and S. Mukerji, 2002, "A Smooth Model of Decision Making Under Uncertainty," mimeo.

Knight, F., 1921, Risk, Ambiguity, and Profit, (Houghton, Mifflin: Boston, MA).

Macey, J. and M. O'Hara, 1998, "The Economics of Listing Fees and Listing Requirements," *Journal of Financial Intermediation*.

Macey, J., O'Hara, M. and D. Pompilio, 2003, "Down and Out in the Stock Market: The Law and Finance of the Delisting Process," Working Paper, Cornell University.

Maenhout, P., 2004, "Robust Portfolio Rules and Asset Pricing," *Review of Financial Studies*, 17 (4), 951-983.

Merton, R., 1987, "A simple model of capital market equilibrium with incomplete information," *Journal of Finance*, 42, 483-510.

O'Hara, M. 2003, "Presidential Address: Liquidity and Price Discovery," *Journal of Finance*.

O'Hara, M., 2004, "Searching for a New Center: U.S. Securities Markets in Transition," *Economic Review*, Federal Reserve Bank of Atlanta, May.

Paiella, M., 2006, "The Foregone Gains of Incomplete Portfolios," Centre for Studies in Economics and Finance, Working Paper No. 156, University of Salerno.

Parlour, C. and D. Seppi, "Liquidity-based Competition for Order Flow," *Review of Financial Studies*, Summer 2003, 16(2), 329-355.

Savage, L.J., 1954, The Foundations of Statistics, Dover.

Schmeidler, D., 1989, "Subjective Probability and Expected Utility without Additivity, *Econometrica*, 57, 571-587.

Vissing-Jorgenson, A., 2002, "Limited Asset Market Participation and the Elasticity of Intertemporal Substitution," *Journal of Political Economy*, 110, 825-853.

Zhang, I. X., 2005, "Economic Consequences of the Sarbanes-Oxley Act of 2002," Working Paper, University of Rochester.