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Signal or noise? Uncertainty and learning about whether other traders are informed ☆

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ABSTRACT

We develop a model where some investors are uncertain whether others are trading on informative signals or noise. Uncertainty about others leads to a nonlinear price that reacts asymmetrically to news. We incorporate this uncertainty into a dynamic setting where traders gradually learn about others and show that it generates empirically relevant return dynamics: expected returns are stochastic but predictable, and volatility exhibits clustering and the "leverage" effect. The model nests both the rational expectations (RE) and differences of opinions (DO) approaches and highlights a link between disagreement about fundamentals and uncertainty about other traders.

1. Introduction

As early as Keynes (1936), it has been recognized that investors face uncertainty not only about fundamentals, but also about the underlying characteristics and trading motives of other market participants. Asset pricing models have focused primarily on the former, taking the latter as common knowledge. For instance, in Grossman and Stiglitz (1980), uninformed investors know the number of informed investors in the market and the precision of their signals. Similarly, each investor in Hellwig (1980) is certain about both the number of other investors and the distribution of their signals. Arguably, this requires an unrealistic degree of knowledge about the economy — it seems unlikely that investors who are uncertain about fundamentals, know, *with certainty*, whether other investors are privately informed.

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We develop a framework in which rational uninformed traders are uncertain whether others trade on informative signals or noise. This uncertainty generates an equilibrium price that is nonlinear in the information about fundamentals, and reacts more strongly to bad news than to good news. When risk considerations are large enough, the price may even *decrease* with additional good news. We incorporate this uncertainty into a dynamic environment in which uninformed traders gradually learn whether others are informed by observing prices and dividends. Return dynamics are also asymmetric — future return moments are more sensitive to lagged returns for negative realizations. The combination of uncertainty and learning generates predictability in expected returns, and can lead to volatility clustering, in which large absolute return realizations are followed by higher expected returns and volatility.

In order to explain the intuition for these results, a brief overview of the model is useful. There is a risky asset in fixed supply that pays a stream of dividends, and there are two groups of investors in the market at any given time. The first group of traders (θ) may be one of two types. They are either informed investors ($\theta = I$), such as institutions, who trade on a signal that is informative about next period's dividend. Or, they are noise traders ($\theta = N$), such as retail investors, who trade on a spurious signal that they (incorrectly) believe to be informative.[1] The second group consists of uninformed rational traders (U), such as hedge funds or liquidity providers, who do not have private information and are uncertain about the type of other investors in the market. All agents have mean–variance preferences and trade competitively in a centralized market by submitting limit orders.

Our benchmark model is static: uninformed traders face uncertainty about whether θ traders are informed but they do not learn about them. In equilibrium, the price and residual demand reveals the signal of the θ investors to uninformed traders, but they are uncertain whether it is informative. Because of this, a surprise in the signal (in either direction) increases the uninformed traders' posterior variance about fundamentals. As a result, the equilibrium price is (i) nonlinear in the signal, and (ii) depends on the probability that uninformed traders assign to θ investors being informed.

An immediate implication is that the price reacts asymmetrically to information about fundamentals.[2] Because they are uncertain whether it is informative, a surprise in the signal increases the uninformed investors' posterior variance about fundamentals. A negative surprise also lowers their expectation about fundamentals and both effects lead to a decrease in the price. A positive surprise increases their conditional expectation, but is offset by the increase in uncertainty. As a result, the price is more sensitive to negative surprises than to positive surprises. When the overall risk concerns are sufficiently large, the effect of the additional uncertainty dominates and the price *decreases* following additional good news about fundamentals. This occurs despite the fact that with good news, θ investors demand strictly more of the asset at any price.

We extend the benchmark model to a dynamic setting. The asymmetry in price reactions to news about fundamentals leads to an asymmetry in return dynamics. Using simulated data, we find that the sensitivity of future return moments to lagged returns is larger for negative realizations of lagged returns. This is consistent with the so-called "leverage" effect, though the mechanism in our model underlying this prediction does not rely on leverage.[3] Rather, it is driven by uninformed traders' uncertainty about others, which causes return changes associated with negative realizations of the θ investor's signal to be larger than the changes corresponding to positive realizations of the same magnitude.

An additional feature of the dynamic setting is that, over time, uninformed traders update their beliefs about whether others are informed using realized prices and dividends. The endogenous evolution of their beliefs (combined with (i) and (ii) above) implies that expected returns and volatility are stochastic, but predictable, and vary with uninformed traders' beliefs about others. Learning about whether others are informed also naturally gives rise to volatility clustering.[4] Since uninformed traders form their conditional expectations of next period's dividends based on their inference about other traders' signal, a dividend realization that is far from their conditional expectation (i.e., a large dividend surprise) leads them to revise downward the probability of others being informed. In other words, large dividend surprises, which are accompanied by large absolute return realizations, reduce the likelihood that θ investors are informed. This can increase uninformed traders' overall uncertainty and, therefore, leads to higher volatility and higher expected returns in future periods.

Our framework bridges the gap between two common approaches to modeling belief heterogeneity and disagreement across investors: *rational expectations* (RE) and *difference of opinions* (DO). In DO models, disagreement arises due to heterogeneous priors, while in RE models, it is due to differences in information. Both are nested within our framework — when the probability that other investors are informed is one (zero), our model is a standard RE

[1] DeLong, Shleifer, Summers, and Waldmann (1990), Hirshleifer, Subrahmanyam, and Titman (2006), and Mendel and Shleifer (2012) use similar specifications for noise (or *sentiment*) traders.

[2] Asymmetric price reactions have been well documented in the empirical literature. For instance, Campbell and Hentschel (1992) document asymmetric price reactions to dividend shocks at the aggregate stock market level. At the firm level, using a sample of voluntary disclosures, Skinner (1994) documents that the price reaction to bad news is, on average, twice as large as that for good news. Skinner and Sloan (2002) document that the price response to negative earnings surprises is larger, especially for growth stocks.

[3] The leverage effect, which refers to the negative correlation between lagged returns and future volatility, has also been widely documented empirically (e.g., Black, 1976; Christie, 1982; Schwert, 1989; Glosten, Jagannathan, and Runkle, 1993; Andersen, Bollerslev, Diebold, and Ebens, 2001; Bollerslev, Litvinova, and Tauchen, 2006).

[4] Since Mandelbrot (1963), a large number of papers have documented the phenomenon of volatility clustering for various asset classes, and at different frequencies. See Bollerslev, Chou, and Kroner (1992) for an early survey.