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Heterogeneous noisy beliefs and dynamic competition in financial markets☆

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ABSTRACT

This paper analyzes the competition of heterogeneously informed traders in a multi-auction setting. We obtain that the competition can take different forms depending on the number of traders, trading rounds and the noise in the information. When the number of traders is small and the number of trading rounds is large, traders may trade very aggressively at the opening and at the end of the trading day with lower trading intensity in between. Hence, we can explain volume patterns by the nature of the competition between traders rather than by pattern in the level of liquidity. We find that the noise in the signal may be beneficial for traders when the competition is strong as it gives them a monopolistic position on their private information. The amount of noise maximizing the trader's expected profit increases with the number of trading rounds as well as the number of traders. This implies that the value of information is closely related to the market where that information is subsequently being used.

1. Introduction

It is now commonly accepted that people hold divergent opinions on many subjects ranging from the future performance of a particular stock to the future growth rate of the economy. These diverging opinions may not be the result of any irrationality but the result of the information processing or the source of the information itself. This information or belief heterogeneity is thought to be the main driving force behind the large trading volume observed in financial markets (see Cochrane, 2007). The recent literature acknowledges the importance of the heterogeneity of beliefs and it has become a central assumption to very diverse analyses (see for instance, He et al., 2009; De Kamps et al, 2014; Gollier, 2007; Verardo, 2009). Xiong (2013) provides an excellent literature review on the subject. Some of that literature focuses on the impact of belief heterogeneity on asset pricing. Gandhi and Serrano-Padial (2015) find that it affects returns and Anderson et al. (2005) find that it might explain the observed favorite-long shot bias. Ottaviani and Sørensen (2014) obtain that when traders are credit constrained the competitive equilibrium price underreacts to information and that this underreaction is larger the more heterogeneous beliefs are.

In our paper, we assume that traders have heterogeneous beliefs regarding the future value of a traded asset. We then study the competition between these traders. Given that framework, we derive the unique linear equilibrium in a multi-auction market where traders receive heterogenous signals.

Our article aims at answering several questions such as what dynamic strategies should informed market participants use to maximize their profits? How quickly does the price adjust to reflect private information? How are the insiders' profits affected by noisy private signals? Can informed traders reduce competition when they have noisy private signals i.e. can noisy information be profitable for informed traders? And as a natural extension to the previous is there an optimal level of noise that maximizes traders' profits?

When looking at the informed trader's behavior we obtain the following results which depend on the level of noise in the trader's signal. When the trader's private information is precise, traders trade very aggressively on their private information. Insiders have very similar private information and try to exploit their private information very early during the trading day and increase their trading aggressiveness until the closure of the market. However, when the trader's private information is very noisy, traders can limit the size of their orders as they have a monopolistic position on the private

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information they have received. In that case, traders wait to exploit their informational advantage as, due to the noise in the signals, prices will take time to incorporate their private information. We find that the effect of the number of auctions, the number of traders and the level of noise do not have a straightforward effect on the competition between traders. Increasing the number of trading rounds leads to more aggressive traders if there are few traders, whereas if there are many traders they may trade aggressively at the beginning and at the end of the trading day. This leads to a pattern in the volume traded whereby the volume is high at the opening and at the closure of the market and lower between the two. This pattern is observed in financial markets. Our paper explains it as being a consequence of the number of trading rounds, the number of traders and the level of the noise.

We are not the first ones to analyze the strategic trading behavior of informed traders in a dynamic setting. Different frameworks have been used to perform that task. Kyle (1985) examines the trading behavior of a single perfectly informed trader and finds that the trader limits the size of his early trades in order not to reveal too much information too early. Information is then gradually incorporated into prices. That result depends critically on the presence of a single informed trader and also on the structure of the private information i.e. whether it is perfect or not. Holden and Subrahmanyam (1992) show, to the contrary of Kyle (1985), that the competition resulting from the presence of more than one informed trader with identical information results in almost all the private information to be revealed in the early auctions.[1] Foster and Viswanathan (1996) analyze the case of imperfect competition when the traders' information is correlated. Back et al. (2000) study the competition between strategic traders in continuous time. Both papers show that the competition between informed traders is very complex and depends critically on the initial correlation between the informed traders' signals. Those two papers are the closest to our analysis. They find that when the correlation is not too strong, the competition has two phases. Firstly, insiders trade very aggressively and release much of their private information in the earlier trading periods. This phase is known as the "rat race". Secondly, since the correlation between the residual private information of the informed traders evolves over time, after a number of auctions the insiders' residual information is negatively correlated between each other. This reflects a difference of opinion between the informed agents about the final value of the risky asset. The informed participants then become more reluctant to trade, since each insider could be on the wrong side of the market. Hence, the trading activity is less intense. This phase is known as the "waiting game". During that phase, insiders conceal their private information. This phenomenon leads to an adverse selection problem in the market at the end of the trading day. Hence, the competition between the insiders does not automatically lead to more efficient prices as one approaches the time of liquidation. Our result regarding the very intense competition when the level of noise is low is close in spirit to that rat race described in Holden and Subrahmanyam (1992), Foster and Viswanathan (1996) and Back et al. (2000).[2] However, when private information is very noisy we only obtain a waiting game. This result is in sharp contrast to Foster and Viswanathan (1996). Indeed, they find that the waiting game is followed by a rat race. In this case, the insiders limit their orders since their private information is noisy. The waiting game observed in our model is not due to a negative correlation between the signals as a consequence of trading. We show that the waiting game phase appears when the correlation between the signals of the traders is low — but positive. We also show that it is possible to have the reverse sequence of the two stages (first a rat race and then a waiting game).

As a natural consequence of the previous results we find that when competition is strong (the number of informed traders and/or the number of auctions is large), increasing the noise in the traders' private information may lead to higher profits. In that case, traders can make more profits with noisy information than with perfect information. This can be explained by the fact that increasing noise gives a monopolistic position on the information received (increasing expected profits). However, adding too much noise in the traders' signals may decrease their profits as it leads traders to trade on noise too (this has a damaging impact on the expected profits). When the level of competition is not as strong, noise always reduces the profit of the informed traders. Whether one effect dominates the other one depends on the level of competition in the market as well as the level of noise. These results generalize the findings of Dridi and Germain (2009). This trade-off between noise and competition bears some similarities with the results put forward by Foster and Viswanathan (1996) and Back et al. (2000) regarding the level of correlation of the signals and the expected profits of the traders. Indeed, Foster and Viswanathan (1996) show that the expected profits of the traders are higher when there is some positive correlation compared to the case where the signals are uncorrelated.

Given the trade-off between competition and noise, we find the existence of an optimal level of noise (i.e. a level of noise maximizing the informed traders' expected profits). This optimal level of noise increases with the number of traders and with the number of auctions. As competition increases the noise maximizing expected profits increases. This result shows that the value of information is closely related to the market where that information is subsequently being used. In a highly competitive market, informed traders would be willing to pay a higher price for a noisier information. This would imply that companies specialized in the sale of information could introduce that in their pricing.

We model the heterogeneity of beliefs differently than Foster and Viswanathan (1996) and Back et al. (2000) but similarly to Kyle (1985) and most of the papers following that model. This enables us to study the effect of the heterogeneity of beliefs onto the competition between traders as in the two first papers cited. We are then able to analyze the direct impact of noise on trading and study the trade-off between noise and competition in a dynamic setting highlighted in Dridi and Germain (2009).[3] This analysis has some relevance for the models of sale of information and more particularly for models of direct sale of information as per Admati and Pfleiderer (1988a). In a direct sale of information, the buyer of information observes the information and trades on it. Obviously an important aspect of the information is the noise embedded in it. One of our result leads to the fact that traders may actually be better off by buying noisy information for use in a very competitive market.

The heterogeneity of beliefs as we model it has also a theoretical appeal. Indeed, considering the effect of the variance of the noise on the traders' behavior (as we do) is not equivalent to considering the effect of the correlation between signals. A change in the correlation between signals only measures the degree to which signals are identical or not. A change in the variance of the noise in the traders' signals does not only affect the correlation between the traders' signals, but also the correlation of the traders' signals with the liquidation value of the asset. Then, changing the level of the noise simultaneously affects the correlation between the traders' signals and the correlation with the liquidation value of the asset. Indeed, a large variance of the noise leads to a lower correlation between

[1] Foster and Viswanathan (1993) find the same result.

[2] We show that the models of Kyle (1985) (discrete setting) and Holden and Subrahmanyam (1992) are encompassed in our model leading to the same results for some particular parameters values.

[3] The model of Dridi and Germain (2009) is a particular case of our model corresponding to a static setting.