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journal homepage: www.elsevier.com/locate/econmodHerding, social network and volatility[☆]Guocheng Wang^a, Yanyi Wang^{b,*}^a Institute of Quantitative and Technical Economics, Chinese Academy of Social Sciences, Beijing 100732, PR China^b School of Finance, Renmin University of China, Beijing 100872, PR China

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ABSTRACT

Investors' expectations are highly influenced by their surroundings' opinions, especially from those who are believed as gurus. These opinion leaders (i.e., gurus) may manipulate the information when the information is disseminated to their followers. It is unclear whether herding behaviors will still emerge in this situation and if so, how these behaviors would influence the market volatility. In this paper, we model agents who choose either to follow the gurus with different precisions of information, or to be a chartist based on evolutionary considerations. Numerical simulations show that increasing the quality of gurus' private information would lead to more intensive herding behavior of followers and produce a U-shaped effect on the market volatility. Besides, increasing the proportion of gurus in the market would lead to more intensive herding but would decrease the market volatility. Interestingly, the market environment also affects investors' choices. Investors are more willing to herd on gurus in boom times or in depression. This paper sheds light on how informed gurus affect investors' behavior and market volatility through direct communication.

1. Introduction

Individuals' investment decisions are inevitably influenced by others. In the financial market, uncentralized influences might lead to herding behaviors. Specifically, herding refers to the convergence in the behavior of investors, analysts and firms in their respective decisions. Such convergent behaviors could be caused by agents' observations of predecessors' actions (e.g. Scharfstein and Stein, 1990; Banerjee, 1992; Bikhchandani et al., 1992; Welch, 1992; Ellison and Fudenberg, 1993; Trueman, 1994; Schlag, 1998; Cipriani and Guarino, 2008), or the observations of the aggregate consequences of actions (e.g. the market price) (Grossman and Stiglitz, 1976; Lux, 1995; Avery and Zemsky, 1998; Smith and Srensen, 2000; Cipriani and Guarino, 2008; Dasgupta et al., 2011).

Previously, much theoretical research has explained agents herding through observational learning: investors infer the information from actions of previous investors and emulate these actions subsequently. For example, the seminal works by Banerjee (1992) and Bikhchandani et al. (1992) find that upon observing a sequential trading of others, people would simply imitate others' actions and disregard their own

information. They suggest that people might overvalue the information represented in decisions made by others, even though their private information might suggest alternatives. The ignorance of their own information would exert a 'negative externality' on the rest of participants, and engender irrational decisions based on ill-defined fundamental value in the market (Banerjee, 1992).

Herding behavior could also simply build up through direct communication in a social network (Ellison and Fudenberg, 1995; Shiller, 1995). Much research has shown that people do benefit from the information advantage through networks in many activities, such as job search (Ioannides and Loury, 2004), stock recommendations (Cohen et al., 2010) and venture capital investments (Hochberg et al., 2007). At the same time, sharing the same information can also result in herding decisions with purblind consideration. In fact, recent empirical literature has demonstrated that individuals are highly influenced by their social peers and incline to take similar actions in a variety of finance-related decisions such as stock market participation (Hong et al., 2004; Brown et al., 2008), corporate finance policies making (Fracassi (Forth coming), 2016), portfolio choice (Hong et al., 2005; Ivkovi and Weisbender, 2007; Heimer, 2016), investment

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returns (Ozsoylev et al., 2014), and welfare plan participation (Bertrand et al., 2000).

In the financial market, when price perfectly reflects most information, the distributed information from an informed agent seems to be more valuable, which will ignite people to trade in the same direction sightlessly. Herding by direct communication thus may have two opposite effects on market outcomes. On the one hand, if the informed agent conveys precise and authentic signals, the information would be impounded into the price more quickly, and the market would operate more efficiently. On the other hand, however, spreading unavailing information would lead to less informative price and greater market volatility (Bommel, 2003). From the followers' perspective, it is hard to distinguish whether this unavailing information comes from an intentional manipulation or an innocent mistake. This leaves space for the occasional manipulation by the informed ones to disseminate the information besides altruism in a network (Battaglini, 2004).

In the prior research, the possibility of information manipulation in direct communication has been overlooked to the understanding of herding behavior. Specifically, it is unclear whether the herding behavior will still be formed if the information through direct communication might be manipulated. If so, what factors would affect the intensity of herding behavior, and how market volatility will be altered accordingly? Our paper attempts to address these questions by extending the theoretical understanding of herding behavior with respect to information quality. Moreover, our paper also makes methodological contributions by applying a heterogeneous-agents asset pricing model in the study of market volatility. The advantage of using agent-based models is that they are capable of simulating a complex system where a number of agents interact through prescribed rules. This will handle a wide range of behaviors that cannot be explained by conventional equilibrium models (Farmer and Foley, 2009). This is particularly suitable for our research purposes. In our study, the heterogeneous agents model helps to simulate the complex interactions among different types of agents in their social networks and estimate the market outcomes.

Our model is outstretched from the seminal work by Brock and Hommes (1997, 1998), who introduce the adaptive belief systems, where agents can choose from a finite set of predictors of the future price of a risky asset based on performance measures (e.g. past realized profits). In their model, there are two types of agents: fundamentalists and chartists. Investors switch between these two predictors based on the past realized profits. Under this setting, they identify how an increase in the 'intensity of choice' (i.e. the sensitivity to the difference in profits between these two predictors) can lead to market instability. This work thus provides a good framework to model evolutionary heterogeneous agents in financial market (He et al., 2009; Ke and Shi, 2009; Westerhoff and Wieland, 2010; Di Guilmi et al., 2014; Zhang et al., 2016; Zheng et al., 2017). In particular, it is suitable to elaborate how the strategies of agents with limited rationality could cause anomalies in the market. In a recent work by Lof (2015), for example, he assumes that multiple agents could have different investment horizons. In his work, there are three types of agents: the long-horizon investors who are called fundamentalists, and the short-term investors including rational speculators and contrarian speculators. He shows that this heterogeneity in investment horizon can produce far more excess volatility than a standard present value model. Especially, he mentions that a large fraction of contrarian speculators contributed to the irrational bubble in 1990s stock market. Different from Lofs' work, our model emphasizes the connections among agents beliefs and how agents communications eventually affect market volatility. We assume three type of agents: gurus, informed speculators and chartists. Gurus are those who have private information in the networks. Other investors choose to be informed speculators, who just simply follow the gurus, or chartists, who chase the trend in the market. To some extent, the gurus and informed speculators are both fundamentalists despite the fact that they have different information sources.

Specifically, gurus collect the information and form their expectations by themselves, while informed speculators follow the information given by gurus. This setting outlines a framework for how communications in a social network could shape investors beliefs and affect the market volatility.

We found that the quality of gurus' own information was a core factor that determined whether they would manipulate the information in the direct communication. Interestingly, an increase in the quality of private information would generate a U-shaped effect on market volatility. Specifically, when the private information was highly precise, it would attract more investors to follow gurus and trade on the informative information. This reduced the variance and increased the market efficiency. Meanwhile, gurus were more likely to send opposite information to followers in order to make profits from their precise private information. Even though followers knew that the probability of manipulation was high, they would still follow gurus if the past realized profits were sufficiently high. This led to the deviation from the fundamental value and increased the market volatility. These results provide support to regulate informed trading of insiders and their relatives to ensure the market stability.

In addition, we also investigated other parameters of interest, such as the proportion of gurus, the intensity of choice and the fundamental values in our model, providing a rich set of testable implications. For example, we showed that an increase in the proportion of gurus would lead to more followers and lower the market volatility. When the market has more gurus, the price would be closer to the fundamental value, and followers would gain more if they go after gurus. In the meanwhile, high quality private information will also elicit higher incentives for gurus to manipulate information. The effects of increasing proportion of gurus (i.e. lowering the market volatility) would be less discernible in a market where all the gurus are highly informed. Therefore, this indicated that more diversified views toward the market would decrease the market volatility, and the effects would be more apparent in markets with more poorly informed participants, such as in the emerging markets where individual investors dominate than in the developed market with more well-informed investors or institutional investors.

Our simulation results also showed that when the unconditional expectation of the fundamental value went to extreme (i.e. either high or low), the intensity of herding would be stronger. The intuition is that when the unconditional expectation of the fundamental value is high, for example, a negative signal carries more valuable information than in a normal time. This indicates that investors are more likely to take advantage of the valuable information and herd on others' opinions. The same pattern will hold when the unconditional expectation is low in a bear market. In the meanwhile, however, if we consider the effects of information quality, the aforementioned principle will also apply: the more informed gurus in the market, the more likely the information is manipulated for chasing their own utilities, and hence the market volatility will be higher. Therefore, herding in a bull market or a bear market would increase the volatility in a market with more sophisticated and well-informed investors, while decrease the volatility in a market with more poorly informed participants.

Our research is associated with some recent work on information communication on herding behaviors (Tedeschi et al., 2009; Tedeschi et al., 2012; Jouini and Napp, 2015). For example, Tedeschi et al. (2012) studied the herding effects induced by investors' imitations on gurus expectations. In their model, however, the imitation behavior is endogenously determined by a preferential attachment rule, and all agents are uninformed noisy traders. Therefore, the gurus are endogenously determined by the intensity of imitation. By assuming that gurus own private information with different levels of precision and that they have the opportunities to manipulate the information, our model establishes a more dynamic setting to illustrate how herding and market volatility are influenced by gurus' information.

Another work by Jouini and Napp (2015) also analyzed the impacts

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