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Beauty contest, bounded rationality, and sentiment pricing dynamics

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ABSTRACT

We present a dynamic asset pricing model that incorporates investor sentiment, bounded rationality and higher-order expectations to study how these factors affect asset pricing equilibrium. In the model, we utilize a two-period trading market and investors make decisions based on the heterogeneous expectations principle and the "sparsity-based bounded rational" sentiment. We find that bounded rationality results in mispricing and reduces it in next period. Investor sentiment produces more significant effects than private signals, optimistic investor sentiment increases hedging demand, thus causing prices to soar. Higher-order investors are more rational and attentive to the strategies of other participants rather than private signals. This model also derives the dampening effect of higher-order expectations to price volatility and the heterogeneity expectation depicts inconsistent investor behavior in financial markets. In the model, investors' expectations about future price is distorted by their sentiment and bounded rationality, so they obtain a biased mean from the signal extraction.

1. Introduction

According to Keynes' "Beauty Contest" view of financial markets (see Keynes (2006)), investment decisions are driven by the investors' anticipation of their peers' changing whims rather than actual knowledge and expectations of the investments they trade. This type of behavior introduces a particular form of informational inefficiency whereby investors tend to place a disproportionate weight on public signals for their forecast of asset prices (see Allen et al. (2006)). Furthermore, we show that the beauty contest analogy for financial markets explains only a portion of the issue because when "sparsity-based bounded rational" sentiment investors' demand shocks are persistent, prices reflect average expectations of not only the fundamental value but also the market sentiment and the bounded capacity of cognition.

Traditional asset pricing theory implies that changes in asset prices are dependent on fundamental changes. However, according to the beauty contest theory, Allen et al. (2006) study the role of higher-order expectations (HOEs) in asset pricing and demonstrate the failure of the law of iterated expectations; they find that prices (i) are driven by higher-order expectations about fundamentals, (ii) underweight private information (with respect to the optimal statistical weight), and (iii) are further from fundamentals than investors' consensus. In addition, higher-order expectations differ from first-order average expectations of the asset's payoff. Our paper confirms other findings in the current literature regarding Keynes' beauty contest theory. Bacchetta and van Wincoop (2006, 2008) illustrate the impact of higher-order expectations in the foreign exchange market and in asset pricing. Banerjee et al. (2009) state that higher-order expectations may explain price drift in the stock market and indicate that it is necessary to generate price drift for heterogeneous beliefs. Kondor (2012) proposes that the reason for forming higher-order expectations is that early investors are forced to make guesses regarding information that later investors have obtained. Kondor further proposed that public information polarized higher-order expectations without polarizing first-order expectations. Yang and Cai (2014) study the effect of higher-order expectations on a static sentiment asset pricing model. Cespa and Vives (2015) suggest that short-termism does not necessarily breed informational price inefficiency even when generating beauty contests. Specifically, the primary conclusion of the literature discussed above is that when compared to first order expectations, higher-order expectations will result in significant advantages.

As an alternative explanation to the argument that financial markets are not always informationally efficient and rational arbitrage cannot completely eliminate irrational effects on asset prices, much of the current literature relies on behavioral finance theories, which often differ from traditional assumptions of strict rationality or unlimited computational capacity on investors. Behavioral finance offers two new theories to explain this deviation: investor sentiment and bounded rationality.

One possible explanation for the deviation is that investor sentiment impacts asset price, hence sentimental investors produce a biased

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valuation of the asset (Baker et al., 2012; Kumar and Lee, 2006; Lee et al., 2002; Brown and Cliff, 2004, 2005; Yu and Yuan, 2011; Seybert and Yang, 2012; Cen et al., 2013; Yang and Zhang, 2013; Zhu, 2013; Kim et al., 2014; Ni and Wang et al., 2015). Shleifer and Vishny (1997) and Hong et al. (2012) demonstrate that greater pessimistic or optimistic shocks result in the failure of arbitrageurs to price at the fundamental value. Barber et al. (2009) argue that sentimental investors produce mispricing, such that imbalances in buyer- and seller-initiated small trades alter prices and result in deviations. Empirically, stocks are difficult to estimate and arbitrageurs earn high subsequent returns when sentiment proxies are low (Baker and Wurgler, 2006, 2007); high sentiment increases the profitability of the short cross-sectional return anomalies (Stambaugh et al., 2012).

Second, Sargent (1993) and Kahneman (2003) provide an introduction to bounded rationality. Researchers utilize a limited number of variables when analyzing a specific problem (Miller 1956). Kahneman further utilize two systems 1 and 2, where system 1 is the intuitive, largely unconscious system, and system 2 is the analytical, conscious system, that makes use of "mental operations". This decision-making system (mixed systems 1 and 2) is not taken into account when an investor has no time to think and will thus rely on defaults (Gennaioli and Shleifer, 2010). Then, the investor may anchor on a default value and make a partial adjustment toward it (Tversky and Kahneman, 1974). Ding et al. (2014) proposed a dynamic system of investment game which played by two firms with bounded rationality, they found that time-delayed feedback control can be used to control system chaos. Gabaix (2014) and other relevant literature (Gabaix, 2016a, 2016b) propose tractable models of bounded rationality that include all of the above characteristics. Empirical findings demonstrate that a bounded rationality model with cognitive limitation provides a reasonable fit to auto- and cross-covariances of the data, mainly driven by a high degree of intrinsic persistence in output and inflation gap on economic dynamics (Jang and Sacht, 2016).

However, few of the sentiment pricing models consider the higher order expectations or bounded rationality to study how they make effects on sentiment asset pricing, and none of them attempt to combine the two ideas jointly. While this work makes some theoretical contributions to previous static models such as Yang and Cai (2014) by generalizing multi-trading, time-varying sentiment and bounded information between different periods.

This study provides three primary contributions to current literature: **First,** in contrast to previous literature on the sentiment asset pricing model, we present an innovative sentiment asset pricing dynamic model with higher-order expectations to analyze how higher-order expectations impact sentiment asset pricing. Nevertheless, when considering the impact of time-varying sentiment effects on the equilibrium prices, the model with dynamic setting has a better capacity to capture changes in the market than static models. **Second,** our model demonstrates the importance of incorporating the expectation heterogeneity of two types of investors with different orders into the asset pricing model, which focuses on inconsistent investor behavior in financial markets. This contribution distinguishes our model from many other models that contain only single first-order or higher-order expectations investors; we detail interactive trading behavior between heterogeneous expectation order investors and determine who gains or loses from trading on a different expectations order. This is a vital issue that may not be explained by ordinary single expectation order investor models. **Third,** we employ "sparsity-based bounded rationality" to further characterize the irrationality of investors and are able to identify which investors have bounded information, a sparse view of the world, and bounded computational capacity. In our model, the investor weighs the cost of having an imperfect decision against the benefits of saving on "thinking costs" (see Yang and Liang (2016)).

The remainder of this paper is organized as follows: We set up a benchmark model utilizing a first-order expectations investor. Section 2 introduces the "sparsity-based" bounded rationality operator. Section 3 builds a second-order expectations dynamic model to illustrate the role of investor sentiment and bounded rationality on second-order expectations equilibrium, and describes the equilibrium characterizations. Section 4 demonstrates how investor expectations heterogeneity of investor sentiment and bounded rationality impacts asset prices. Section 5 presents comparative statics, while Section 6 provides concluding remarks.

2. Benchmark case: A first-order expectations investor model

2.1. Economy

Our goal is to tackles at an essentially difficult problem of asset pricing with higher-order expectations to formalize the discussions outlined in the introduction. One advantage of this model is that we try to incorporate higher-order expectations and bounded rationality in a dynamic setting. The starting point here is Allen, Morris and Shin (AMS) model (see Allen et al. (2006)), where it is shown that when investors form expectations about expectations of others, the law of iterative expectations will fail and consequently price will deviate from the fundamental value in the way that it reacts to the changes slower than under rational (Bayesian) reasoning.

And then in this section, we study a first-order expectations investor (henceforth first-order investor) dynamic to develop our intuition and key insights. The model here involves three periods and the focus is on the price in the period 2, the last period before the fundamental value is revealed. The first idea that we explore is the impact of the higher order expectation on price.

Consider an economy with a continuum of investors of unit measures indexed by i. Time is discrete and there are three periods t=0, 1, 2 and 3. There is one single risky asset that trade over time and will be liquidated on date 3.

The liquidation value of the asset θ is determined prior to trading on date 0 and is a normally distributed random variable with mean P_0 and variance$1/\alpha$, where the initial P_0 is also the price of the risky asset, and α describes the precision of the public signal. In period 0, all investors share the same initial public signal. In period 1, investor i may observe a private signal about θ that satisfies: $v_{1i}^{S_1} = \theta + IS_1 + \varepsilon_{1i}^{S}$, the precision of the private signal on date 1 is $\tau_v^{S_1}$, P_1 is the price of the asset on date 1. This investor may also observe a private signal that satisfies $v_{2i}^{S_2} = \theta + IS_2 + \varepsilon_{2i}^{S}$ in period 2, where the precision is $\tau_v^{S_2}$. Clearly, in the model, the precision of the private signal is the reciprocal value of the variance.

As a convention, we hold that$P_3 = \theta$, where the sentiment terms IS_1, $IS_2 \sim N(0, 1/\sigma)$ are i.i.d. across investors i. As in our previous static model (see Yang and Cai (2014)), IS represents the measure of average errors in forming a private signal, which is normally distributed with mean 0 and variance $1/\sigma$ and monotonically increases with increases in the market sentiment S as follows[2]:

(1) If $S > 0, IS > 0$, investor$i$is optimistic and forms an overconfident private signal, $v_i^S > v_i^R$.
(2) If $S < 0, IS < 0$, investor i is pessimistic and forms a low mean private signal, $v_i^S < v_i^R$.
(3) If $S = 0, IS = 0$, investor i is rational and $v_i^S = v_i^R$.

Similarly, we also set the cognitive fundamental of investors are changing when investors are impacted by different market sentiment, thus the aggregation of private signals deviates in the influence of market sentiment.

[2] Notice that S here is the market sentiment, while investor sentiment SI is an independent realization from S.

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