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Asset prices, traders' behavior and market design

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ABSTRACT

The dynamics of a financial market with heterogeneous agents are analyzed under different market architectures. We start with a tractable behavioral model under Walrasian market clearing and simulate it under different trading protocols. The key *behavioral* feature of the model is the switching by agents between simple forecasting rules on the basis of a fitness measure. By analyzing the dynamics under order-driven protocols we show that the behavioral and structural assumptions of the model are closely intertwined. The high responsiveness of agents to a fitness measure causes excess volatility, but the frictions of the order-driven markets may stabilize the dynamics. We also analyze and compare allocative efficiency and time series properties under different protocols.

1. Introduction

Models of financial markets often assume a simplistic mechanism for market clearing: the Walrasian scenario. This observation also applies to an innovative research area of heterogeneous agent models (HAMs), wherein the heterogeneity of traders' expectations is a key to explaining the properties of markets. In reality, however, markets function in a different way. Agents are allowed to transmit only a finite amount of information in the form of orders to buy or sell. Furthermore, many markets employ continuous trade in the form of sequential orders. In this paper we study the impact of market organization on the dynamic properties of the asset pricing model populated by adaptive, boundedly rational agents with heterogeneous forecasting rules. We demonstrate that the adaptive abilities of the agents can be impaired by frictions inherent in the order-driven mechanisms. Surprisingly, this may stabilize the price dynamics. We also analyze how the market efficiency and statistical properties of prices are affected by the interplay of behavioral and institutional assumptions.

Statistical properties of real financial data have been thoroughly investigated in the past, see for example Fama (1970), Pagan (1996), Brock (1997), and Cont (2002). This line of research established a number of regularities in financial data, so-called "stylized facts," many of which are observed universally in all time periods and on different stock exchanges. Some of these regularities, for example the absence of significant autocorrelations in price returns, are well in agreement with the prevailing theory, called the Efficient Market Hypothesis, which suggests that markets are informationally

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efficient, i.e., new information is immediately reflected in asset prices. At the same time, such regularities as large and persistent trading volume, significant positive autocorrelations in variance of returns (volatility clustering), and heavier-than-normal tails of the return distribution are left unexplained within the classical paradigm. A seminal paper by Shiller (1981) detected that asset prices are more volatile than underlying fundamentals. The discovered excess volatility undermined the completeness of the Efficient Market Hypothesis.

Explaining these empirical properties by means of a simple model is an important but difficult task and there are several different directions, which deviate from the classical paradigm with a rational, representative agent (see, e.g., Lucas, 1978) leading to this goal. One way is to acknowledge that the assumption of full rationality is too demanding in the complex environment of financial markets. Models with heterogeneous agents using a bounded rational procedure as proposed in Sargent (1993) and Evans and Honkapohja (2001) may be more appropriate. A number of agent-based simulations of markets and rigorous analytical HAMs have been developed, which allow agents with different expectations to coexist in one market.[1] If one group of agents, called *fundamentalists*, believes that price typically reflects a fundamental value, and another group, *chartists*, extrapolates price trends, then the prices in a market can deviate from the fundamental value when chartists are in a majority. In Brock and Hommes (1998), this simple story is augmented by the evolutionary dynamics of relative fractions of fundamentalists and chartists. In this Adaptive Belief System agents not only update their forecasts as new data become available but also switch from one forecasting technique to another depending on techniques' past performances. Gaunersdorfer et al. (2008) show that even a simple version of such an adaptive model can generate dynamics with some realistic properties. Since the extrapolative expectations of chartists can be self-confirming, prices can deviate from the fundamental level and exhibit excess volatility. Furthermore, for certain parameter values the underlying deterministic system possesses two attractors, the fundamental steady state and a cycle around it, with small volatility for the former and high volatility for the latter. When dynamic noise is added to the system, price trajectory can interchangeably visit the basins of these two attractors producing volatility clustering. Gaunersdorfer and Hommes (2007) show that with a sufficiently large level of noise, this model indeed generates the dynamics that are qualitatively similar to a real market.

Alternatively, one can focus on the market design as a possible origin of stylized facts. Many classical models and all the HAMs quoted above use a Walrasian auction (WA) as a market clearing mechanism. It may be the case, however, that specific design features of the real markets bring some structure into the data. Simulations in Cohen et al. (1978) imply that the limit order book (OB) causes significant return autocorrelations. LiCalzi and Pellizzari (2003) show that an artificial market with realistic architecture, namely an order-driven market under electronic book protocol, is capable of generating satisfactory statistical properties of price series (e.g., leptokurtosis of the returns distribution) even with minimal behavioral assumptions. Furthermore, simulations in Bak et al. (1997) and Maslov (2000) suggest that desirable distributional properties can arise in the order-driven market even in the absence of any behavioral assumptions on the side of the agents.

These two streams of literature model either behavioral or structural features, but not both and, therefore, may provide only a partial explanation for the statistical regularities of financial markets. As opposed to those studies, recent agent-based models in Chiarella and Iori (2002), LeBaron and Yamamoto (2006), and Chiarella et al. (2009) incorporate the agents' heterogeneity in the order-driven markets. However, the interplay between behavioral and structural assumptions is far from trivial in these models, so that it often becomes difficult to understand how the two sets of assumptions contribute to the models' results. Consequently, our approach in this paper will be to start with a parsimonious model, which is analytically tractable under a WA, and then increase the complexity by adding price- and order-driven trading protocols. The latter versions of the model are investigated through computer simulations.

Our research strategy is largely inspired by the work of Bottazzi et al. (2005). Motivated by empirical evidence from the world's stock exchanges that market micro-structure does influence statistical properties of returns, they compare dynamics under different trading protocols in the market populated by two types of traders: *chartists* and *noise traders*. The proportions of both types are *fixed*. Bottazzi et al. find that market architecture plays a larger role in shaping the time series properties than the behavioral aspects of the model. The authors also analyze the allocative efficiency of the market and show that, as opposed to the time series properties, the allocative efficiency depends mainly on the traders' behavior.

This paper follows a similar research strategy. However, in contrast to Bottazzi et al. (2005), our model is based on the *adaptive belief system* of Brock and Hommes (1998). In our model the market is populated by *fundamentalists* and *trend-followers* whose proportions are *evolving* on the basis of differences in past profits. A key behavioral parameter of the model is the intensity of choice, measuring the sensitivity of agents to this difference. If the market clears in the Walrasian way and the number of agents approach infinity, our model can be approximated by the deterministic model similar to the one analyzed in Gaunersdorfer et al. (2008). With our choice of forecasting rules, there exist two regimes in the market: tranquil and volatile. When the intensity of choice is low, i.e., smaller than a certain critical value, there is no excess

[1] The Santa Fe artificial market introduced in Arthur et al. (1997) and the model of microscopic simulations in Levy et al. (2000) are two known examples of a computational approach focused on bounded rationality in the formation of expectations. They are accompanied by parsimonious models in Day and Huang (1990), Lux (1995), Brock and Hommes (1998), Chiarella and He (2001), Farmer and Joshi (2002), Diks and van der Weide (2005), Anufriev et al. (2006), and Anufriev and Dindo (2007). See LeBaron (2006) and Hommes (2006) for recent reviews focused, respectively, on computational and analytical models with heterogeneous agents.