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Price dynamics in a market with heterogeneous investment horizons and boundedly rational traders

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ABSTRACT

This paper studies the effects of multiple investment horizons and investors' bounded rationality on the price dynamics. We consider a market with one risky asset with agents maximizing expected utility of wealth over discrete investment periods. Investors' demand for the risky asset may depend on the historical returns, so that our model encompasses a wide range of behaviorist patterns. Stochastic properties of the returns process are established analytically and illustrated by simulation. The links between dynamic patterns in returns and different types of investment behavior are explored in the heterogeneous agents' framework. We find that conditional volatility of returns cannot be constant in many generic situations, especially if agents with different investment horizons operate on the market. In the latter case, the return process can display conditional heteroscedasticity, even if all investors are so-called "fundamentalists" and their demand for the risky asset is subject to exogenous *iid* shocks. We show that the heterogeneity of investment horizons can contribute to the explanation of different stylized patterns in stock returns, in particular, mean-reversion and volatility clustering.

1. Introduction

The heterogeneous agents literature focuses on how the expectations of market agents affect risky asset price dynamics. According to their expectations, investors are often classified as "fundamentalists", "chartists" and "noise traders". The interaction of heterogeneous agents, their herding behavior and strategy switching modify the noise process and create persistent trading volume, excess volatility, fat tails, clustered volatility, scaling laws (see Hommes, 2006; LeBaron, 2006 for surveys on interacting agents models). Andersen (1996) interprets the aggregated volatility as the manifestation of numerous heterogeneous information arrivals. Limits to arbitrage, market psychology, heuristics and biases, which are subject of behavioral finance, can also be helpful to explain empirical evidence (see Barberis and Shleifer, 2003).

A number of analytically solvable models were proposed to explore the dynamics of financial market with heterogeneity coming from boundedly rational beliefs of investors about future returns. Brock and Hommes (1998) proposed a model, where investors switch between a number of strategies according to expected or realized excess profits. Stylized simple strategies describe patterns in investors' behavior that are commonly observed empirically—chartism and trend-following. More recently, Chiarella and He (2001), Chiarella et al. (2006), Anufriev et al. (2006), Anufriev (2008) and

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Anufriev and Dindo (2010) study artificial markets where CRRA investors follow heterogeneous strategies and maximize an expected utility. They make investment decisions depend on wealth, which is undoubtedly more realistic but technically more difficult than when CARA utility is used. Vanden (2005) introduces a more sophisticated step-wise dependence of the risk aversion on wealth and finds that this can have important consequences for return dynamics. Recently Weinbaum (2009) showed that heterogeneous risk preferences and risk sharing can be a source of volatility clustering.

The starting point of our study is the model of Anufriev et al. (2006) where a risk-free and a risky asset are traded by heterogeneous agents on a Walrasian market (further referred to as ABP model). The model is studied analytically only in its deterministic skeleton. The authors determine the fixed points in the asset returns and wealth dynamics and study the stability conditions of the equilibria.[1] This paper employs the ABP framework but adopts a different strategy. We analytically study the stochastic return dynamics on the equilibrium path and in the neighborhood. The equilibrium path corresponds to the case when investors are fundamentalists and have rational expectations (*i.e.* perfectly predict the parameters of the return dynamics in equilibrium).

The deviations of investors' beliefs from those in the rational expectation case, interpreted as bounded rationality, can be modeled as shocks to the dynamic system. They are considered along with other types of shocks that may be related to the market imperfections and the deviations of the price of the risky asset after the trades from the one obtained in the Walrasian mechanism. The impact of these shocks is studied both analytically and by simulation. We establish direct relationships between investors' behavior and dynamic properties of returns (their conditional mean, volatility, autocorrelations). Throughout the paper, we consider the particular case of mean–variance investors and a fairly general case, when the demand of the risky asset depends only on past returns. We show that the degree to which the rationality of the agents' belief is bounded has an impact on the return dynamics. In the particular case of mean–variance investors, imposing very weak conditions on the beliefs coherence reduces the continuum of equilibria to one point.

The second and the central contribution of this paper is that it incorporates a new source of investor heterogeneity: that of the investment horizons. By investment horizons, or scales, we mean typical periods between two consecutive adjustments of investment portfolio, peculiar to a certain type of investors. The heterogeneity of the market with respect to agents' operations frequency is further referred to as the Multiple Investment Scales (MIS) hypothesis. We suppose that investors maximize expected utility of wealth at the end of some investment period. We call the typical length of this period the investment horizon (or scale).

The effect of heterogeneity in investment horizons is also addressed in Anufriev and Bottazzi (2012). They derive a fixed point for the price of the risky asset dynamics under the assumption that agents maximize expected CARA utility over different periods in future. But their model disregards the effect of various frequencies of portfolio adjustments and, due to the constraints of the CARA assumption, does not realistically account for the dynamics of wealth. They conclude that heterogeneity of investment horizons alone is not enough to guarantee the instability of the fundamental price and the emergence of the non-trivial price dynamics, such as volatility clustering or serial correlations. In this paper we derive a different conclusion, which is close to that obtained in Chauveau and Topol (2002). Working in a different framework, they explained volatility clustering of OTC exchange rates by market microstructure effects, unifying intraday and interday dynamics. Edelstein and Qian (2009) claims that the heterogeneity in investment horizons can be helpful to explain the dynamics of the prices on the housing market.

Though not examining the MIS hypothesis analytically, several earlier studies evoke the heterogeneity of investment horizons as a possible explanation of the stylized facts in stock price volatility. The assumption that price dynamics is driven by actions of investors at different horizons serves as a microeconomic foundation of the volatility models in Müller et al. (1997). They suppose that there exist volatility components, corresponding to particular ranges of stock price fluctuation frequencies, that are of unequal importance to different market participants. These participants include intraday speculators, daily traders, portfolio managers and institutional investors, each having a characteristic time of reaction to news and frequency of operations on the market. So frequencies of price fluctuations depend on the periods between asset allocation decisions, and/or the frequencies of portfolio readjustments by investors.

An important result obtained in this paper is that even in the absence of (i) contrarian and trend-following investors and of (ii) heterogeneous information arrivals on the market our interacting agents model can reproduce some stylized facts of the return dynamics. We show that, under some conditions, volatility clustering can arise in an economy populated with fundamentalist traders only, given that their portfolios are adjusted with different frequencies and that their demand of the risky asset occasionally deviates from the level, corresponding to the rational equilibrium. These deviations need not necessarily follow particular trading patterns. We also propose a study of the joint effect of the MIS hypothesis and of the bounded rationality in investment strategies.

The rest of the paper is organized as follows. In the next section we introduce the general setting of the model. Section 3 describes the equilibria in the one-scale model with boundedly rational investors, re-examining the conclusions of the ABP model in a stochastic setting and preparing the ground for the study of the multi-horizon case. In Section 4 we derive the equilibrium in the MIS case and establish the properties of the return dynamics. In Sections 5–7 we present simulation

[1] The stochastic properties of returns have been studied in other papers, mentioned above, in particular by Chiarella et al. (2006) in a somewhat similar wealth-driven CRRA setting. But the patterns in stochastic dynamics are almost exclusively studied by the simulation method.