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Wealth-driven selection in a financial market with heterogeneous agents☆

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ABSTRACT

We study the co-evolution of asset prices and individual wealth in a financial market with an arbitrary number of heterogeneous boundedly rational investors. Using wealth dynamics as a selection device we are able to characterize the long run market outcomes, i.e., asset returns and wealth distributions, for a general class of competing investment behaviors. Our investigation illustrates that market interaction and wealth dynamics pose certain limits on the outcome of agents' interactions even within the "wilderness of bounded rationality". As an application we consider the case of heterogeneous mean-variance optimizers and provide insights into the results of the simulation model introduced by Levy, Levy and Solomon (1994).

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1. Introduction

Consider a financial market where a group of heterogeneous investors, each following a different strategy to gain superior returns, is trading. The open questions are to specify how their interaction affects market returns and who will survive in the long run. This paper seeks to give a contribution to this issue by investigating the co-evolution of asset prices and agents' wealth in a stylized market for a long-lived financial asset with an arbitrary number of heterogeneous agents. We do so under three main assumptions. First, asset demands are proportional to agents' wealth, so that market clearing prices and agents' wealth co-evolve. Second, each individual investment behavior can be formalized as a function of past returns. Third, the dividends of the risky asset follow a geometric random walk.

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By focusing on asset prices dynamics in a market with heterogeneous investors, our paper clearly belongs to the growing field of Heterogeneous Agent Models (HAMs), see Hommes (2006) for a recent survey. We share the standard set-up of this literature and assume that agents decide whether to invest in a risk-free bond or in a risky financial asset.[2] In the spirit of Brock and Hommes (1997) and Grandmont (1998) we consider a stochastic dynamical system and analyze the sequence of temporary equilibria of its deterministic skeleton.

Whereas the majority of HAMs consider only a few types of investors and concentrate on heterogeneity in expectations, our framework can be applied to a quite large set of investment strategies so that heterogeneity with respect to risk attitude, expectations, memory and optimization task can be accommodated. Employing the tools developed in Anufriev and Bottazzi (2009) we are able to characterize the long-run behavior of asset prices and agents' wealth for a general set of competing investment strategies, which can be specified as a function of past returns.

An important feature of our model concerns the demand specification. In contrast to many HAMs (see, e.g., Brock and Hommes, 1998; Gaunersdorfer, 2000; Brock et al., 2005), which employ the setting where agents' demand exhibits constant absolute risk aversion (CARA), we assume that demand increases linearly with agents' wealth; that is, it exhibits constant *relative* risk aversion (CRRA). In such a setting agents affect market price proportionally to their relative wealth. As a consequence, relative wealth represents a natural measure of performance of different investment behaviors. On the contrary, in CARA models the wealth dynamics does not affect agents' demand, implying that a performance measure has to be introduced *ad hoc* time by time. Furthermore, experimental literature seems to lean in favor of CRRA rather than CARA (see, e.g., Kroll et al., 1988 and Chapter 3 in Levy et al., 2000).

The analytical exploration of the CRRA framework with heterogeneous agents is difficult because the wealth dynamics of every agent has to be taken into account. Although there has been some progress in the literature (see, e.g., Chiarella and He, 2001, 2002; Anufriev et al., 2006; Anufriev, 2008 and Anufriev and Bottazzi, 2009), all these studies are based on the assumption that the price-dividend ratio is exogenous. This seems at odd with the standard approach, where the dividend process is exogenously set, while the asset prices are endogenously determined. In our paper, to overcome this problem, we analyze a market for a financial asset whose dividend process is exogenous, so that the price-dividend ratio is a dynamic variable. Our paper can thus be seen as an extension of Anufriev and Bottazzi (2009) to the case of exogenous dividends.[3]

As a result we show that depending on the difference between the growth rate of dividends and the risk-free rate, which are the exogenous parameters of our model, the dynamics can converge to two types of equilibrium steady-states. When the growth rate of dividend is higher than the risk-free rate, the equilibrium dividend yield is positive, asset gives a higher expected return than the risk-free bond, and only one or few investors have a positive wealth share. Only such "survivors" affect the price in a given steady-state. However, multiple steady-states with different survivors and different levels of the dividend yield are possible, and the range of possibilities depends on the whole ecology of traders. Otherwise, when the dividends' growth rate is smaller than the risk-free rate, the dividend yield goes to zero, both the risky asset and the risk-free bond give the same expected return, and the wealth of all agents grows at the same rate as asset prices. Notice, however, that convergence to either types of steady-state equilibria is not granted. We show how local stability of each steady-state depends on the strength of the price feedback, occurring via the investment functions.

An important reason for departing from previous works with CRRA demands is that it allows for a direct application to a well known simulation model. In fact, our CRRA setup with exogenous dividend process is identical to the setup of one of the first agent-based simulation model of a financial market introduced by Levy, Levy and Solomon (LLS model, henceforth); see, e.g., Levy et al. (1994). Their work investigates whether stylized empirical findings in finance, such as excess volatility or long periods of asset overvaluation, can be explained by relaxing the assumption of a fully-informed, rational representative agent. Despite some success of the LLS model in reproducing the financial "stylized facts", all its results are based on simulations. Our general setup can be applied to the specific demand schedules used in the LLS model and, thus, provides an analytical support to its simulations.

As we are looking at agents' survival in a financial market ecology, our work can be also classified within the realm of *evolutionary finance*. The seminal work of Blume and Easley (1992), as well as more recent papers of Sandroni (2000); Hens and Schenk-Hoppé (2005); Blume and Easley (2006, 2009) and Evstigneev et al. (2006), investigate how beliefs about the dividend process affect agents' dominance in the market. A key difference between our model and the evolutionary finance approach is that our agents can condition their investment decisions on past values of endogenous variables such as prices. As a consequence, in our framework prices today influence prices tomorrow through their impact on agents' demands, generating a price feedback mechanism. In the HAMs such mechanism plays an important role for the stability of dynamics. For instance, when the investment strategy is too responsive to price movements, fluctuations are typically amplified and unstable price dynamics are produced. Indeed, we show that local stability is related to how far agents look in the past.

This paper is organized as follows. Section 2 presents the model and leads to the definition of the stochastic dynamical system where prices and wealths co-evolve. The steady-states of the deterministic version of the system are studied in

[2] Recently, also some models with heterogeneous agents operating in markets with multiple assets (Chiarella et al., 2007) and with derivatives (Brock et al., 2006) have been developed.

[3] The CRRA framework with exogenously growing dividends has been also investigated in Chiarella et al. (2006a), but under a different mechanism of market clearing, i.e., market-maker scenario. The focus of their analysis is also somewhat different from ours. They study the return dynamics with two specific types of traders, fundamentalists and chartists, rather than in general as we do.

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