



Market equilibria under procedural rationality[☆]

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ABSTRACT

We analyze the endogenous price formation mechanism of a pure exchange economy with two assets, riskless and risky. The economy is populated by an arbitrarily large number of traders whose investment choices are described by means of generic smooth functions of past realizations. These choices can be consistent with (but not limited to) the solutions of expected utility maximization problems.

Under the assumption that individual demand for the risky asset is expressed as a fraction of individual wealth, we derive a complete characterization of equilibria. It is shown that irrespectively of the number of agents and of their behavior, all possible equilibria belong to a one-dimensional "Equilibrium Market Curve". This geometric tool helps to illustrate the possibility of different phenomena, as multiple equilibria, and can be used for comparative static analysis. We discuss the relative performances of different strategies and the selection principle governing market dynamics on the basis of the stability analysis of equilibria.

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1. Introduction

There exists a long-standing tradition in theoretical economics to model economic agents as having a strictly limited range of notionally available actions. Maximization of a suitable function (e.g. expected utility) is widely accepted as a reasonable description of individual behavior, as it captures the idea of rationality and profit seeking behind the actions of the "economic man". As early as fifty years ago, however, some writers, most notably Herbert Simon, recognized a strong dissonance between the modeling of human behavior in economics and the description of the same behavior in other social sciences. Indeed Simon (1955) emphasizes that, due to informational and cognitive restrictions, people may not be acting as if they were utility maximizers who are able to perfectly anticipate their own and others' future decisions and reactions. At the same time, however, it is in general true that human beings avoid behaving in a random manner. Rather they tend to follow

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some deliberate procedures in their decision making process. This broader view on economic behavior led to the concept of *procedural* rationality (Simon, 1976) which still includes, as a special case, the optimizing and perfectly anticipating behavior but which can, at the same time, account for different types of learning.

The assumption of procedurally rational agents implies that the level of heterogeneity in the market is much larger than it is usually assumed. As argued by Kirman (2006) this heterogeneity is probably fundamental for the functioning of market economies. Notice that, in principle, even “substantive rational” agents imbued with perfectly anticipating rationality may differ in terms of their preference structure and, hence, in their implied actions. At the same time, heterogeneity in expectations is reported in several surveys on traders behavior and is the basis for several proposed explanations for the abnormal large trading volume in financial markets and for other observed “anomalies” (e.g. Brock, 1997; Hommes, 2006 and references therein). Such “rational heterogeneity” is broadened and strengthened by the various violations of axioms of rational choice which have been well documented by a number of different studies in the field of experimental economics.²

If the evidence supports the idea of procedural rationality of heterogeneous agents, why do the models based on that assumption remain exceptions rather than norm? In his review of the literature on bounded rationality, Conlisk (1996) identifies a number of possible reasons for the dominance of substantive rational behavior in economic modeling. One of them is that such behavior, even if not entirely realistic, seriously restricts the range of possible actions, and, hence, brings discipline into the theory. By acknowledging the need of discipline, this paper seeks to dispel the fear of getting lost in the “wilderness of bounded rationality”. In the context of a simple speculative asset market our model demonstrates that (i) market forces and (ii) a natural requirement for consistency between aggregate dynamics and individual actions will lead to quite specific conclusions about the long-run state of the market.

We consider a dynamic model where an arbitrary number of heterogeneous agents trade a riskless bond and a long-lived risky asset. The only restriction imposed on the individual behavior is that the amount of asset demanded by traders is expressed as a fraction of their current wealth. In technical terms, this assumption confines possible agents' behavior to the so-called constant *relative* risk aversion (CRRA) framework. The shares of personal wealth invested in the risky security are chosen, at each period, following individual procedures and on the basis of commonly available information. We model procedural rationality by means of agent-specific *investment functions* which map the information set to the present investment share. The dynamics of the multi-dimensional system describing the evolution of asset price and agents' wealth is derived. Without imposing any constraint about the specific form of the investment functions we are able to completely characterize those equilibria in which aggregate market dynamics is consistent with agents expectations. Equilibrium price return and wealth distribution turn out to be a combined outcome of the agents' adaptive procedures and of the evolutionary selection taking place in the market. Specifically, we show that two types of long-run dynamics are possible. In the first type both securities give the same expected return, and the wealth of all agents grows at the same rate. Conversely, in the second type one of the securities gives a higher expected return, and one or few “survivors” ultimately possess the total wealth of the economy. We derive the local stability results for all possible steady-states. The conditions are ready to be applied for any specific ecology of traders whose behavior can be accommodated in our framework.

Two distinct streams of theoretical research intersect in our paper. The main source of our inspiration is the growing field of the Heterogeneous Agent Models (HAMs), extensively reviewed in Hommes (2006). The HAM literature considers markets as a feedback system, where agents employ adaptive expectation rules, so that current prices affect expectations about future prices, and, consequently, prices themselves. By modeling stylized behaviors of “fundamentalists” or “trend chasers”, the HAMs can explain different “stylized facts” of financial markets, such as excess volatility and repeated patterns of temporary bubbles followed by severe crashes. In our opinion, however, this approach lacks a unifying framework, because expectation rules vary from model to model. By keeping investment functions generic we intend to create such a framework, avoiding, at the same time, an unrealistic level of simplicity in the agents' expectational procedures and considering truly heterogeneous preferences. Furthermore, in the HAMs with evolving population (as e.g. in Brock and Hommes, 1998), agents switch between different forecasting rules on the basis of some performance measure, which is often introduced *ad hoc*. Conversely, the wealth dynamics, explicitly considered in our framework, provide a natural performance measure.³

Multi-asset markets populated by several procedurally rational agents are studied in the literature on Evolutionary Finance (EF), initiated by Blume and Easley (1992), and recently reviewed in Evstigneev et al. (2009). Our paper shares a number of distinctive features with the EF literature, such as a descriptive approach to the investment behavior of agents and the central role played by wealth-driven selection in determining the long-run dynamics of the market.

The EF literature focuses on the relative valuation of different risky assets. It is also specifically interested in those strategies which attract most wealth and are evolutionary stable, i.e. are not driven out by alternative behaviors. In contrast to the EF literature, but in the spirit of the HAMs, in this paper we focus on the nature of market instabilities caused by the adaptive behavior of agents and the feedback mechanism existing between realized and expected mar-

² The Handbook of Experimental Economics (Kagel and Roth, 1995) and the Nobel lecture of Daniel Kahneman (Kahneman, 2003) provides plenty of examples of systematic biases, i.e. individual decisions which would be qualified as irrational from the traditional economic point of view.

³ Notice that many HAMs are built in the so-called constant *absolute* risk aversion (CARA) framework. Asset demand of CARA agents is independent of their wealth, and thus wealth dynamics do not affect asset pricing. Conversely, our CRRA agents have *investment shares* which do not depend on their wealth, so that demand for the risky asset increases linearly with wealth. The inclusion of CARA strategies in a CRRA-based framework is a topic that deserves further research. However, experiments with human subjects usually reject CARA behavior, supporting decreasing or constant relative risk aversion, see for example Kroll et al. (1988) and the discussion of this issue in Levy et al. (2000).

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