Behavioral Finance and Agent-Based Computational Finance: Toward an Integrated Framework

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1 The Current Orthodoxy

One principal objective of financial economists is to understand, to explain and even to predict the macro-phenomena that emerged into the financial markets. To do this, economic model builders seek appropriate micro-foundations of traders' decision-making behavior under risk and uncertainty that are both *empirically plausible* and *analytically tractable*.

Following the neoclassical economics tradition, the orthodox financial theorists often adopted the assumptions that decision-makers possess von Neumann-Morgenstern preference and are *rational* expected-utility maximizers. This solid micro-foundation of decision-making behavior along with some other key assumptions about the whole structure of models, e.g., rational expectations, representative agents, imposed market-clearing conditions, no-arbitrage conditions, etc., constitute the formal framework of the standard finance theory today. In this vein, financial economists constructed numerous highly successful and influential theories, such as the capital asset pricing model (CAPM), efficient markets hypothesis (EMH), and the Black-Scholes option pricing model, among many others. The common features of these models are their *neat structure* and *analytical tractability*. Supported by several empirical studies, the financial economists' view of the financial markets was based on these models until the mid-1980s. In this Utopia, the asset prices react to any new information prevailing immediately, and thus the asset returns are unpredictable. The volatility of asset prices comes mainly from the effects of the fundamental side. The only forces that drive the asset prices and expected returns are economically meaningful risk factors.[1] That is to say, traders can receive return premia solely from bearing market risk. Any *irrational* or *noise* traders will lose money to informed rational arbitrageurs and eventually be eliminated from the market in the long run. By further assuming that it is common knowledge that all traders are rational and that traders share common prior beliefs, the notable *no-trade theorem* holds in these settings. The financial market is complete and thus derivative securities are nothing more than redundant assets. No-arbitrage arguments work pretty well in pricing these assets. The above scenarios are all that we've learned in the standard finance textbook as the core of finance theory.

2 New Facts in Financial Markets

From the late-1980s to the present, financial economists have recognized several new stylized facts, the so-called *financial anomalies*, in their empirical studies.[2] Contrasted with the beauty of the Utopia, the new evidence reveals that the macro-phenomena of real financial markets seem to be strange and anomalous. It is something of an enigma that asset returns do not follow random walks and are somewhat predictable. We can see that returns tend to gain momentum on short horizons, whereas they also suffer a reversal in the long run. Other anomalies include excess volatility of asset prices, the equity premium puzzle, the high trading volume in fi-

[1] To echo Campbell [5, p. 1557], "... asset pricing is concerned with the sources of risk and the economic forces that determine the rewards for bearing risk."

[2] For a survey of these new facts, see Cochrane [7] and [11].

nancial markets, the success of some technical trading strategies in earning excess returns, volatility clustering of stock returns, market bubbles, market crashes, and so on. The new stylized facts prevail in the financial markets and do not seem to disappear from the empirical data for a long while.

These findings have set off series of debates among financial economists. One viewpoint at the very end of the spectrum supported by Fama [9], an eminent EMH defender, is that the anomalies are just chance results, and many of them rely heavily on different econometric methodologies. He thus claims that EMH survives the challenge from the "seemingly" anomalous empirical results. At the other end of the spectrum, Shefrin [16]—and many other behavioral finance advocates—have claimed that in order to have comprehensive understanding of those new facts a paradigm shift is a must. However, even though we accept that we need to depart from the Utopia of EMH, there exist several means to deal with those anomalies observed in the empirical data. The key issues concern what kinds of investors' behavior, market microstructures, and information structures lead to the anomalous market phenomena that we have observed.

In one line of thought, theorists insist on models built upon *rational* agents. *Expected utility theory* (EUT) proposed by von Neumann and Morgenstern was set to be the standard for modeling decision-making under risk and uncertainty just like the mainstream finance theory. Moreover, model builders further assume that agents follow the *Bayesian rules* to process any inflow of new information. As Constantinides [8, p. 1567] put it, "the neoclassical rational economic model is a *unified* model that views these premia as the reward to risk-averse investors that *process information rationally* and *have unambiguously defined preferences over consumption* that typically (but not necessarily) belong to the von Neumann-Morgenstern class." A fully rational economic agent has unlimited computing ability to process all the information he or she has and to make an optimal choice instantaneously. Though assuming that human beings conform to this ideal is never real, we can think that decision makers behave *as if* they were rational. Friedman [10] argued that we should judge the validity of a model by its explanatory power, and not by the reality of the assumptions it made. In order to explain the new anomalous facts that we have, theorists loosen some of the extraneous conditions in the traditional models. Though traders are rational in the model, they may face an incomplete and/or imperfect market. There might exist asymmetric information between different agents. The theory might also consider some of the institutional factors such as transaction costs, and differences among assets in terms of liquidity and tax status. The theorists have obtained some fruitful results and have proposed parts of the reasons and explanations for those enigmatic anomalies. Constantinides [8] has surveyed a series of studies in this vein.

3 The Behavioral Paradigm in Economics and Finance

Another approach, as mentioned earlier, and used to handle the issue of model building in giving explanations to the financial anomalies, is that where theorists resort to borrowing expertise from behavioral psychologists. By accumulating a great bulk of evidence from experiments with human subjects, psychologists have found that the judgment process of human beings can be anything but rational.[3] Practitioners in financial markets use rules of thumb called *heuristics* to deal with information which they get their hands on in the process of decision-making. Behavioral financial economists include these kinds of "normal" (other than rational) agents in their models in order to explain and depict those anomalous phenomena found in empirical studies. Since they believe that human beings always suffer from all kinds of judgment biases, they argue that assuming rationality might lead to a spurious understanding of the true mechanism of financial anomalies.

Psychologists have found that many of the errors humans make in the decision-making processes are neither random nor independent across individuals. Psychologists have thus obtained some robust results that people make several typical systematic errors in their judgment. For example, they have accumulated much evidence that people are prone to be overconfident in their talents and abilities when it comes to making good decisions. People rely heavily on representativeness heuristic that may disobey Bayesian rules. In many cases, the decision-making processes are frame-dependent. In certain other situations, psychologists have some evidences of conservative behavior. All of these findings show that people are not as rational as the neoclassical models

[3] For those psychological studies regarding decision-making by human beings under risk and uncertainty that are relevant to economics and finance, see Barberis and Thaler [4], Hirshleifer [11], and Rabin [15].

assumed and the gap is rather large.

In addition, following the notable work of the late Amos Tverskey and Daniel Kahneman, psychologists and economists started to question the validity of EUT as an appropriate representation of the preferences of human beings. They found in the experiments involving human subjects that people behave in ways that systematically violate EUT when facing risky prospects. In response, Kahneman and Tversky proposed the prospect theory (PT) as a replacement. Along with other studies on non-expected utility theories, researchers seek a better model to fit the experimental findings to take the place of the traditional EUT framework.

With these research results as the microfoundation of financial market theories, financial economists try to figure out the connection between the judgment biases of traders and financial anomalies. These efforts constitute the young field of behavioral finance which is promising and is growing rapidly.[4] For example, in some models, economists have shown that the irrational behavior of traders brings about limits to arbitrage, and thus the financial markets fail to be efficient. In others, overconfidence might result in overreaction to new inflows of information, while conservatism might lead to underreaction.

Note that a large number of the studies in the field of behavioral finance still retain the framework of representative agents, say, representative *irrational* agents with judgment biases whose preference does not obey EUT. However, representative agent models have serious flaws in that they ignore the very nature of the heterogeneity of human beings. Whom or what does the representative agent represent [12]? Can we just assume that one specific kind of judgment bias prevails among the whole group of financial markets? As aptly depicted by Arrow [2, p. S390]:

> ... the *homogeneity assumption* seems to me to be especially dangerous. It denies the fundamental assumption of the economy, that it is built on gains from trade arising from *individual differences*. Further, it takes attention away from a very important aspect of the economy, namely, the effects of the distribution of income and of other individual characteristics on the working of the economy [*italics added*].

To put it clearly, though we have robust evidence that people err in some decision-making situations, they might not all behave in the same way. First, psychologists' demonstrations of the biases people display are based on the *majority* choices of respondents to *hypothetical risky choice problems*. Note that there is no single response to hypothetical problems with which respondents are all in agreement. That is to say, human beings have, more or less, diverse ranges of behavior under certain risky situations. Therefore, psychologists' behavioral theories might be good at depicting the decision-making behavior of respondents at large, but they would never cover all of them. Secondly, most of the hypothetical problems designed by experimental psychologists are elementary, one-shot gambles with different prospects. None of them try to catch a dynamic context. We may put a question mark over the validity of these theories in terms of applying them to situations of this kind. As a result, introducing experimental results into highly dynamic financial models (e.g., asset pricing) needs to be treated with great caution.

4 Financial Markets as Complex Adaptive Systems

There is still another viewpoint to the existence of financial anomalies where the paradigm departs from the neoclassical one even farther. Without a doubt, financial markets are complex adaptive systems (CAS). Thousands of heterogeneous autonomous traders are involved in the market place. They learn to earn and survive. They interact with each other and with the evolving environment that they, themselves, constitute. As Arthur [3, p. 107] puts it, "Complexity portrays the economy not as deterministic, predictable, and mechanistic, but as process dependent, organic, and always evolving." Based on this view of financial markets, the macrophenomena will always be changing and will be rich and colorful.

To model financial markets as complex adaptive systems, we face the difficulties of analytical tractability. Imagine how we can get neat close-form equilibrium solutions in this kind of evolving complex system. Fortunately, agent-based simulation techniques provide a platform to do this. This field, which is still in his infancy, is referred to as agent-based computational economics/finance (ACE/ACF) [1, 6, 13, 14, 18].

Following the CAS paradigm, ACF models the

[4] For comprehensive surveys about recent studies on behavioral finance, see Barberis and Thaler [4] and Hirshleifer [11].

financial market as a combination of heterogeneous adaptive agents. If the market phenomena come from the very nature of learning and interacting among heterogeneous agents, traditional representative agent models, regardless of whether they are rational or irrational, cannot give us a true understanding. It is the learning, adapting and evolving abilities that we give to our agents in the agent-based models that can deal with some issues which complement the neoclassical and behavioral approaches. Instead of extraneously imposing a specific kind of behavioral bias, e.g., overconfidence or conservatism, on the agents, we can canvass the emergence and/or the survivorship of this behavioral bias in the highly dynamic and complex environment by computer simulation. Agent-based modeling may lead us to some viewpoints by pushing beyond the restrictions of the analytical approach.

5 Conclusion

This paper depicts three categories of research trying to reveal the underlying mysteries behind well-recognized financial market phenomena, for instance, the anomalies. The first is rational agents models, the second is behavioral models, and the third is agent-based models. We argue that agent-based modeling is a promising approach that catches the important feature of real financial markets, that is, the very nature of complex adaptive systems. Analytical behavioral models may provide a starting point for agent engineering in agent-based models, while agent-based modeling lets us test whether a specific kind of judgment bias of traders can emerge and survive in the complex competitive market place.

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