

Inefficient Markets:
Alternative Approaches to Modeling Financial Markets

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1 Introduction

The strong form of efficient markets hypothesis (EMH) asserts that in the financial markets, prices of traded assets always reflect all known information and that it is not possible to outperform the market using information that the market already knows. Despite the popularity of EMH among academic theorists, this theory has been accepted by very few market participants. Aimed at grasping the reason behind this, this paper will explore a few alternative ideas, covering the adaptive market hypothesis (AMH) in Behavioral Finance and the Santa Fe Institute Artificial Stock Market (SFI-ASM) game theoretic model. AMH is an evolutionary approach to economic interactions which implies that the degree of market efficiency is related to environmental factors characterizing market ecology such as the number of competitors in the market, the magnitude of profit opportunities available, and the adaptability of the market participants. The SFI-ASM model (Palmer *et al.*, 1994) is an agent-based model with adaptive expectations and a tool which has become popular in studying markets.

This paper offers an overview of EMH, AMH, and SFI-ASM and provides the motivation for finding a suitable alternative model to EMH. Section 2 introduces the concept of efficient market hypothesis, and Section 3 analyzes the conflicts between the theorists and financial investors. Sections 4 and 5 discuss AMH and SFI-ASM, respectively. I find that because the alternative models take on a broader set of assumptions, specifically about the bounded rationality of humans, it reaches a set of conclusions that are more similar to the observed conditions of real financial markets.

2 Efficient Markets Hypothesis

Neoclassical economics, the most widely taught form of economics, is built on a set of assumptions which includes that markets are efficient and that humans act rationally. Under

these assumptions, economists generally and have historically believed that financial markets act efficiently in reflecting all available information. This property was given the name “efficient markets hypothesis.” The origins of efficient markets hypothesis dates back to 1965 when Samuelson published his proof that properly anticipated prices fluctuate randomly (Samuelson, 1965). Five years later, Professor Eugene Fama proposed the efficient markets hypothesis: because markets are efficient and current prices fully reflect all available information, it is impossible to consistently outperform the market, except through luck (Fama, 1970). At this point, it is imperative that the term “efficient” be well defined. Fama characterizes an efficient market as one “where there are large numbers of rational, profit-maximizers actively competing, with each trying to predict future market values of individual securities, and where important current information is almost freely available to all participants” (Fama, 1965). Efficient markets do not allow investors to earn above-average returns without accepting above-average risks.

The conclusion that is drawn under these conditions is that competition among the many intelligent participants leads to an equilibrium where actual prices of individual securities already reflect the effects of information based both on past events and on future events expected to occur. Note, however, that this “available information” refers to information that is readily available to all investors. If we assume that information can be kept private (insider information), then the market would be inefficient to the extent that this secret bit of information would change the market if it were public knowledge instead. To handle these types of differences in what information is available, there are three forms of the efficient market hypothesis, each of which have different implications on how markets work. The “weak” form asserts that only past data is fully reflected in security prices. The “semi-strong” form claims

that all publicly available information is reflected in prices. Finally, the “strong” form asserts that security prices reflect all information.

In referring to EMH, this paper will take on the assumption that all information is publicly available, and therefore consider only the “strong” form unless otherwise specified. An implication of EMH is that any kind of analysis (fundamental, technical, etc.) would be as useful in choosing a profitable investment as flipping a coin. Most investors disagree with this conclusion, and research in behavioral finance have attempted to prove the existence of market trends which would suggest that stock prices do not move randomly (Lo, 1999).

3 Problems with the Efficient Markets Hypothesis

There is a discrepancy in beliefs about the financial markets: economists believe in market efficiency and a lack of speculative opportunities, whereas market traders believe in the opposite. Stock market analysts have observed that technical trading (using past price movements to predict future prices) has been consistently profitable for some professional investors (Frankel and Froot, 1990), and that temporary price bubbles and crashes are sometimes caused by herd effects rather than simply a reflection of rational changes in asset valuations. From a trader’s standpoint, George Soros, a very famous financial speculator, said this about the efficient markets hypothesis:

This interpretation of the way financial markets operate is severely distorted... It may seem strange that a patently false theory should gain such widespread acceptance, except for one consideration; that is, that all our theories about social events are distorted in some way or another (Soros, 1994).

The problems with efficient market hypothesis stems from the fact some of the assumptions do not translate well into real financial markets. First of all, investors do not always act rationally. Behavioral finance attempts to understand and explain how human emotions

influence investors in their decision-making process. Bounded rationality reflects the limited cognitive abilities that constrain human problem solving. Other findings of behavioral finance include bounded willpower, which captures the fact that people sometimes make choices that are not in their long-run interest and bounded self-interest which incorporates the comforting fact that humans are often willing to sacrifice their own interests to help others. Secondly, stock prices are not only determined by a calculation of all supporting information but also by how investors perceive the information. To illustrate this point, in the next section I will examine the financial market dynamics for various initial states of the population. I will show that the weight each component has depends on the composition of the population.

There are two types (or strategies) of investors: those who believe that speculative opportunities exist (strategy S) and those who believe that the market is efficient (strategy E). We will analyze situations based on tools from evolutionary game theory. First, imagine a market in which the population of all investors believed in the efficient markets hypothesis. Suppose that a small group of investors with strategy S enter the market. In attempting to achieve above-average returns, these investors take on a cost in order to analyze data. However, this analysis provides no expected profits because all stock prices will move randomly when everyone expects markets to be efficient. Therefore, the small population would not do as well in the market as those who believe in EMH in this situation. Now, imagine a market in which the population of all investors had strategy S and a small group of investors with strategy E entered the market. In this case, most investors would take on a cost to analyze data, but it would be very profitable to do so since the popularity of this speculative opportunity would immediately raise the stock price up. Note that there is a very high variance in this type of market because as soon as a slight shift in perception changes, the entire market will shift

dramatically. Compared to the previous example, a market filled with speculative investors is certainly not as efficient in deriving the intrinsic value of the good as a market filled with EMH investors. The financial market can become a self-fulfilling prophecy if a large enough proportion of investors have the same strategy. Notice that in both examples, the beliefs of a majority of investors characterized the investment opportunities and price movements of the market.

To conclude this discussion about problems with the efficient market hypothesis, let us observe that the efficient market hypothesis comes with a paradox. If every investor believed the market was efficient, then no one would analyze data. In order for the market to be efficient and information to be gathered and analyzed, efficient markets hypothesis requires there to be investors who attempt to exploit market inefficiencies (these are the ones who analyze data). If there is no opportunity to make a profit by analyzing data in an efficient market then the intrinsic value of every investment will never be known, which causes the market to be inefficient.

4 Adaptive Markets Hypothesis

Introduced in 2004 by Andrew Lo, adaptive markets hypothesis is an application of evolutionary ideas to economic behavior. Rather than taking a neoclassical approach of attempting to maximize expected utility and assuming rational expectations, AMH has an evolutionary perspective and views individuals simply as organisms that have adapted through generations of natural selection to maximize the survival of their genetic material. Lo summarizes adaptive markets hypothesis as a model in which “the dynamics of evolution, mutation, reproduction, and natural selection— determine the efficiency of markets and the waxing and waning of financial institutions, investment products, and ultimately, institutional

and individual fortunes” (Lo, 2004). This perspective implies that behavior is not necessarily intrinsic and exogenous but evolves by natural selection and depends on the particular environment through which selection occurs.

Consequently, the principles that guide AMH are: individuals act in their own self interest, make mistakes, and learn and adapt. In addition, competition drives adaptation and innovation, natural selection shapes market ecology, and evolution determines market dynamics. Note that this set of assumptions is much less binding than those of EMH. Under AMH, there are speculative opportunities do exist in the market (Lo, 2005). However, these opportunities appear and disappear over time, so innovation is the key to survival. Unsuccessful investors, the ones who continue to make maladaptive decisions, are eventually eliminated from the population.

Using only qualitative analysis, Lo found that this model is able to explain certain counterexamples to economic rationality, such as loss aversion, overconfidence, overreaction, mental accounting, and other behavioral biases. Another advantage adaptive markets hypothesis has over EMH is that it can deal with bounded rationality and potential for opportunism. Although this model is currently only in a qualitative state, it does provide a new framework on how to think about financial markets.

5 The Santa Fe Institute Artificial Stock Market

The Santa Fe Institute Artificial Stock Market was developed by Brian Arthur, John Holland, Blake LeBaron, Richard Palmer, and Paul Taylor in 1994. This model is an agent-based game model in which traders continually develop strategies to predict future prices in financial markets. The market contains a fixed number of players N who are each endowed with

an initial wealth W_0 . The game is played through multiple stages and so time is measured in discrete intervals. At the beginning of each period, the players rely on their prediction strategy to determine what they want in their portfolio. Also in each period, players have the option to change their prediction strategy to a more profitable one based on recent performance. Traders have a choice between investing in risk-free assets and risky stocks. The risk-free assets are the equivalent to treasury bills since there is an unlimited supply and the rate of return is a constant interest rate r . Thus the opportunity cost a player faces for choosing a risky stock is r . There are N shares of the risky stock that pays an uncertain dividend d at the end of the period. All traders have an identical constant absolute risk-aversion utility of wealth function:

$$U(W_{i,t+1}) = -e^{-\lambda W_{i,t+1}}$$

At each round, the players choose between the risk-free asset and risky stock independently, but the payoffs depend on the decisions of all of the players. Players have the option to revise their method of forecasting the stock's future price, so we will let forecast revision rate refer to the rate at which players revise their stock picking rules. This game is essentially a prisoner's dilemma game. Traders are interested in maximizing their own profits. They will choose to increase their revision rates because it is a strictly dominating strategy, even though everyone is better off if they can agree to slow down the revision rate of their market-forecasting rules. Although cooperation can emerge among self-interested players in iterated two-person prisoner's dilemmas (Axelrod, 1984), it has been shown to be almost impossible to achieve in an N-person game (Lindgren, 1998).

In any case, past research has shown that the market's behavior is consistent with efficient markets hypothesis if traders revise their forecasts infrequently (Palmer *et al.*, 1994).

However, this market condition is unsustainable due to the enforcement problems of dealing with a large number of market participants. There is a unique equilibrium in this market, but it is not socially optimal (Joshi *et al.*, 2002). At the equilibrium where all market players revise their rules frequently, trading systems become more sophisticated. If enough traders in the market adopt similar technical trading rules, then the positive feedback can make the rules self-fulfilling prophecies. Recalling a conclusion from section 2, if the population consists of mostly speculative traders, the market will be volatile and inefficient. Thus, the SFI-ASM model allows us to observe some important elements of decision making in the financial market without having to assume perfect rationality.

6 Conclusion

This paper has summarized two promising new ideas that might someday refute the relevance of the efficient market hypothesis, which has been in place for over thirty years. The evolutionary approach taken by AMH provided a different perspective how the markets change over time and whether or not they are efficient. The SFI-ASM agent-based model, on the other hand, is useful in replicating the behavior of financial markets. Recent research has shown that in this game, the unique strategic Nash equilibrium is suboptimal in the sense that the market is inefficient.

Unlike EMH, these two models both were able to deal with uncertainty, bounded rationality, and agent heterogeneity that underlie learning and decision making in most real markets. Whereas EMH is very useful framework to consider for certain situations, it is important to have a working model in more general cases as well. A broader set of assumptions will allow us to eventually reach this point. Much research still remains to be done to further both the development of AMH and the game theory analysis of SFI-ASM. In order for AMH to

become a more useful tool, quantitative tools need to be developed for adaptive markets hypothesis just as they were developed for EMH.

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