BEHAVIORAL FINANCE, BOUNDED RATIONALITY, NEURO-FINANCE, AND TRADITIONAL FINANCE

K.C. Tseng*

Abstract

The principal purpose of this study is to piece together the important development and contributions by efficient market hypothesis, bounded rationality, behavioral finance, neurofinance, and the recently introduced adaptive market hypothesis. In the process the author will review the selected literature so that they can be linked together for further consideration and development. When monthly and daily data for S&P 500, DJIA, and NASDAQ indexes were analyzed from 1971 to 2005, the author found long string of positive and significant autocorrelations and great volatility, which were not consistent with the efficient market hypothesis. The international market indexes from Japan, Hong Kong, Singapore, Mexico, Taiwan, and Canada are also very volatile even though they show less volatility compared to the U.S. indexes. Since AMH was introduced in 2004, it is promising but is still at its infant stage of development. Finally, the neural/medical finance can help us understand the brain activities when investors are making investing and trading decisions, and the effect of drugs on brain and investment decision-making. The future of neurofinance and AMH appears to be promising.

Key words: adaptive market hypothesis, affect and emotion, behavioral finance, bounded rationality, efficient market hypothesis, excessive volatility, neurofinance, and psychophysiology.

JEL classification: N2, N20.

1. Introduction

In recent years new fronts have been rapidly developing in investments and financial markets. In particular, the behavioral finance, evolutionary finance, and neurofinance are challenging the traditional finance. Whether the financial markets, in particular the stock markets, are efficient or not and whether market participants are rational or not, depend to a large extent on the ways people look at the markets. They look at exactly the same empirical evidence or findings, but they may interpret the observations quite differently. People are yet different biologically, genetically, in education and training, in experience, in opportunities, and many other aspects. Financial market participants and researchers have diversified background in education, training, experience, investment objectives, available information, time constraint, capability of analyzing and processing available data, and the ability to predict the future uncertain conditions. Active investors and academic researchers are quite different in many aspects just mentioned. Technical analysis, which is inconsistent with efficient market hypothesis (EMH), has been an important tool for most market participants since the beginning of financial markets. The key controversy between proponents of EMH and advocates of behavioral finance centers on the extent or degree of market efficiency, investors' rationality, and interpretations of many empirical findings.

The theoretical foundations of EMH rest on three basic assumptions. First, market participants are perfectly rational and are able to value securities rationally. Second, even if there are some investors who are not rational, their trading activities will either cancel out with one another or will be arbitraged away by rational investors (Shleifer, 2000). Finally, market participants have well defined subjective utility functions which they will maximize.

According to Simon (1982, vol. 2, p. 408), "Rationality denotes a style of behavior that is appropriate to the achievement of given goals, within the limits imposed by given conditions and constraints. Theories of rational behavior may be normative or descriptive, that is, they may prescribe how people or organizations should behave in order to achieve certain goals under certain

*Craig School of Business, California State University at Fresno, USA.

conditions, or they may purport to describe how people or organizations do, in fact, behave." When risk and uncertainty or incomplete information about an alternative or high degree of complexity is introduced, people or organizations may behave somewhat different from rationality. This led to his well-known new concept called bounded rationality. The following quotation is from Simon (1997, vol. 3, p. 291):

> *The term 'bounded rationality' is used to designate rational choice that takes into account the cognitive limitations of the decision-maker, limitations of both knowledge and computational capacity. Bounded rationality is a central theme in the behavioral approach to economics, which is deeply concerned with the ways in which the actual decision-making process influences the decisions that are reached.*
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> *The theory of subjective expected utility (SEU theory) underlying neo-classical economics postulates that choices are made: (1) among a given, fixed set of alternatives; (2) with (subjectively) known probability distributions of outcomes for each; and (3) in such a way as to maximize the expected value of a given utility function (Savage, 1954). These are convenient assumptions, providing the basis for a very rich and elegant body of theory, but they are assumptions that may not fit empirically the situations of economic choice in which we are interested.*

The first foundation of EMH therefore is at best to be modified to bounded rationality, or as a strong supporter of market rationality, Rubinstein (2001), called minimal rationality. In addition, as pointed out by Shleifer (2000), because of investors' attitudes toward risk, their non-Bayesian expectation formation, and their sensitivity of decision making to the framing of problems, they tend to deviate from rationality. As to the second foundation of no arbitrage opportunity underlying EMH, the real world arbitrage is not only risky but limited (Shleifer, 2000; Shleifer and Vishny, 1997). Regarding the third theoretical foundation of EMH, it is assumed that investors contemplate everything that lies before them in very comprehensive views ranging from all alternative choices at the moment and over the entire future (Simon, 1983). In the actual financial markets in general and stock markets in particular this condition can never be met.

The supporters of EMH argue that stock market anomalies can be attributable to methodology and techniques used in those studies of abnormal stock returns (Fama, 1998). However, no one can provide any correct or perfect methodology or technique to support that the market has been efficient all the time. He also argues that since overreaction and under-reaction have been observed frequently, the market anomalies are "chance results". Therefore EMH is in tact. Others such as Malkiel (2003) argue that market does not permit investors to earn excess returns without being accompanied by more risk. Malkiel believes that the most direct and convincing tests of EMH are the direct tests of professional fund managers' ability to outperform the market. After adjusting for substantial survivorship bias he found no evidence for the professional fund managers to outperform the market. Unfortunately, the fact that the overall professional fund managers cannot consistently outperform the market is not a proof that the market is always efficient. There have always been superior and inferior professional money managers over a certain period of time. Rubinstein (2001) argues that "the market, as we have seen, has many special features that protect it from aggregating the irrationalities of individuals into prices." But since arbitrage is risky and limited there is no evidence that investors are consistently rational and the market is always efficient. One appealing observation was made by Constantinides (2002) when he indicated that "several examples of apparent deviation from rationality may be reconciled with rational economic paradigm, once we recognize that rational investors have incomplete knowledge of the fundamental structure of the economy and engage in learning". Even rational investors with complete information on relevant factors, they may not have the capability to predict the uncertain future and that uncertain future is critical to investing. The cognitive limitations on knowledge and prediction capability of human decision- making behaviors are important aspects of bounded rationality.

The purpose of this study is to piece together the traditional theory of EMH, the more realistic bounded rationality, the behavioral finance which explicitly incorporate the psychology into

decision-making under uncertainty, neural/medical finance, and the adaptive market hypothesis which takes into consideration the potential contribution from the recent development in evolutionary biology, information technology, neuroscience, psychology, and sociology. In Section 2 the bounded rationality will be applied to stock market and modify the EMH to become more applicable to the real world situations. In Section 3 the role of emotions will be presented. In Section 4 the recent development and contributions of behavioral finance will be discussed. In Section 5 neural/medical finance will be introduced and adaptive market hypothesis will be discussed. Some recent evidence of the auto-correlated and excessive volatile stock markets is presented in Section 6. Conclusions and future research directions will be at the end of this paper.

2. Bounded Rationality

When we apply the concept of bounded rationality to stock market, we can modify the theoretically elegant EMH to become more practical and realistic. The theoretical foundation of EMH is the subjective expected utility theory (SEUT). The assumptions underlying this theory are (Simon, 1983): (1) a decision maker has a well-defined utility function which can be assigned some cardinal number to reflect the possible future events, (2) the decision maker faces a well-defined set of alternatives to choose from, (3) the decision maker is able to assign a consistent joint probability distribution to all future sets of events, and (4) the decision maker will maximize the expected value of his/her utility function. Bounded rationality theories are derived from relaxing some of these purely theoretical assumptions which exist only in Plato's idealistic world. It is worthwhile pointing out that bounded rationality is not irrationality. In other words, market participants in general are bounded rational, but not necessarily irrational.

Let relax the assumption number 2 and assume that alternatives are not fixed but follow some generating process as conditions change. For decision makers such as investors the generating process of alternatives is complex and difficult given the fact that so many factors both domestic and global may impact asset prices and some of these factors may change quickly. Given the limited available time to make decisions it is unlikely the set of alternatives can be complete as assumed in SEUT. Based on modern cognitive psychology and human alternative generating behavior observed in the laboratory, some heuristics aiming at finding some satisfactory alternatives or improved alternatives over previously available ones are more likely. The cognitive limits reflected by the lack of knowledge and predictability of the uncertain future make the evaluation of alternatives difficult. For investors finding alternatives, evaluating them, and making choice among them are always difficult and uncertain.

Regarding the assumption number 3, with the high degree of uncertainty and complexity of the future conditions, it is impossible for any decision maker to have a consistent joint probability distribution of all future events. Instead the decision maker may estimate some probability distributions without assuming the knowledge of probabilities. If both alternatives and probability distributions about the future events are uncertain, the decision maker is unlikely to have a well-defined utility function as assumed in (1) and impossible to maximize a not well defined utility function. The limits of human cognitive ability for discovering alternatives, calculating their outcomes and making comparisons may lead the decision maker to settle for some satisficing strategy (Simon, 1982, vol. 2). Isn't that a typical way of decision making process for most investors?

After reviewing the extant literature on bounded and unbounded rationalities, Conlisk (1996) provides four basic reasons for incorporating bounded rationality into making economic or financial decisions. First, bounded rationality is empirically very important because "There is a mountain of experiments in which people: display intransitivity; misunderstand statistical independence; mistake random data for patterned data and vice versa; fail to appreciate law of large number effects; fail to recognize statistical dominance; make errors in updating probabilities on the basis of new information; understate the significance of given sample size; fail to understand covariation for even the simplest 2x2 contingency tables; make false inferences about causality; ignore relevant information; use irrelevant information (as in sunk cost fallacies); exaggerate the importance of vivid over pallid evidence; exaggerate the importance of fallible predictors; exaggerate the ex ante probability of a random event which has already occurred; display overconfidence in judgment over evi-

dence; exaggerate confirming over disconfirming evidence relative to initial beliefs; give answers that are highly sensitive to logically irrelevant changes in questions; do redundant and ambiguous tests to confirm a hypothesis at the expense of decisive tests to disconfirm; make frequent errors in deductive reasoning tasks such as syllogisms; place higher value on an opportunity if an experimenter rigs it to be the "status quo" opportunity; fail to discount the future consistently; fail to adjust repeated choices to accommodate intertemporal connections; and more" (Conlisk, p. 670).

Second, many economists (including financial economists) have successfully incorporated bounded rationality into their models to describe economic, investment, or market behaviors. Third, specific conditions may favor either bounded or unbounded rationality. Finally, limitations on human cognition must be treated as a scarce resource and therefore the bounded rationality is consistent with the fundamental tenet of economics. Gabaix and Laibson (2000) have developed and tested a boundedly rational decision algorithm which can make quantitative behavioral predictions and is broadly applicable, and empirically testable. Their data overwhelmingly reject the rational model. When affect and emotion are taken into account, human behavior may frequently turn from bounded rationality to irrationality.

3. Emotion: From Bounded Rationality to Behavioral Finance

In a survey article Elster (1998) uses six key characteristics to define emotions. They are: cognitive antecedents, intentional objects, physiological arousal, physiological expressions, valence, and action tendencies. Human motions are triggered by beliefs and therefore differ from other visceral factors as focused by Loewenstein (2000). Animals have visceral factors such as pain, hunger and drowsiness but they do not form beliefs. Emotions have intentional object because they are about something and are closely related to cognitive antecedent. Other visceral factors do not have intentional object. Emotions are caused by hormonal changes and changes in the autonomic nervous system and the resulting observable physiological expressions. Emotions can be measured in pleasure-pain scale. For behavioral emotions high arousal tends to go with high valence, and consequently leads to urgent actions and short circuiting cognition.

Emotions can be useful or valuable. Perfect rationality cannot deal with surprises, misunderstandings, or irresolvable conflicts. Under those circumstances, emotions enable people to coordinate their behaviors, to find appropriate actions, to improve the situations, and enable them to make better decisions. Emotions can help shape the reward parameters for rational choice and enable us to make rational choices within those parameters. The dual role of emotions in shaping choices and rewards is similar to pain, addictive cravings and other visceral factors (Elster, p. 73).

According to Loewenstein (2000),"Visceral factors refer to wide range of negative emotions (e.g., anger, fear), drive states (e.g., hunger, thirst, sexual desire), and feeling states (e.g., pain), that grab people's attention and motive them to engage in specific behaviors" (p. 426). Contrary to the general assertion that visceral factors are erratic and unpredictable, the determinants of visceral factors and their impact on behaviors are highly systematic, but cognitive deliberations are very unpredictable. Even though visceral factors tend to be transient, they can result in long-lasting and significant consequences. Visceral factors may affect all kinds of behaviors. They are normally associated with self-control problems. Visceral factors play an important role in decision-making under risk and uncertainty. People's cognitive evaluations of risks tend to differ from their emotional reactions to those risks. Traditional economists in general and financial economists in particular have left visceral factors out of their analyses because they are perceived to be too unpredictable and complex to formal modeling.

Emotional states are usually divided into hot states such as anxiety, fear, greed, and courage, and cold states of rational calm. The difference between how we behave in hot states and cold states is known as empathy gap. During the hot states market participants are prone to make mistakes which are very likely to result in losses. If the traders can shorten the empathy gap, they are more likely to reverse their mistakes and make decisions consistent with long-term financial returns and satisfaction. Since emotions are related to psychology, physiology, and neurology, they are related to rationality, bounded rationality, behavioral finance, and neural/medical finance. Indeed, emotions have profound influence in the decision-making process.

4. Some Recent Development and Contributions of Behavioral Finance

Kahneman and Tversky (1973) find that investors systematically violate Bayes rule and other maxims of probability theory in predicting uncertain outcomes. People usually forecast future uncertain events by focusing on recent history and pay less attention to the possibility that such short history could be generated by chance. Rabin (1998) pointed out that people tend to weigh heavily on salient, memorable, or vivid evidence even if they have better information. Once strong hypothesis is formed people are often inattentive to new information contradicting their hypotheses, but they often misinterpret the new evidence as additional support for their initial hypotheses. The prospect theory developed by Kahneman and Tversky (1979) find that investors are reluctant to sell losing stocks. In addition, Kahneman and Riepe (1998) find that investors' deviations from the maxims of economic rationality are pervasive and systematic. Along the similar line is that investors tend to overweight recent information and underweight base rate information. De Bondt and Thaler (1985, 1987) find that investors overreact to drastic or unexpected events or information. They find that portfolios of prior losers outperform that of prior winners in the long run. Since investors count on the representative heuristic, they become too optimistic about recent winners and too pessimistic about recent losers. Haugen (1999) argues that inefficient market will lead to positive payoff to cheapness resulting from the market's overreaction to success or failure.

Recently Odean (1998a, 1998b, 1999) finds that investors tend to overestimate their ability, unrealistically optimistic about future events, too positive on self-evaluations, over-weight attention getting information that is consistent with their existing beliefs, and over-estimate the precision of their own private information. He also finds that people exhibit greatest overconfidence when they are dealing with difficult task such as investing in stocks and predicting their future returns. In addition, he finds that overconfident traders trade too much, lower their expected utility, generate greater market depth, and increase volatility. Based on a very large sample of individual investors at a large discount broker, Barber and Odean (2000) find that overconfident investors incline to sell winners too soon and keep losers too long. Barber and Odean (2001) find that online investors tend to be overconfident, trade more frequently, and increase volatility.

Shefrin and Statman (1985) consider four major elements of human behavior, i.e. prospect theory, mental accounting, regret aversion, and self-control in their study. The prospect theory assumes that the value of an alternative is the summed products over specified outcomes x. Each product consists of a value and a weight associated with the objective probability p of obtaining x. The utility in the SEUT is defined in terms of net wealth. The value in the prospect theory is defined in terms of gains and losses of wealth. The prospect theory includes loss aversion, regret aversion, self control and mental accounting in which investors treat each component of their portfolios separately. Based on prospect theory, investors tend to become risk-seekers after realizing gains and risk-averters after suffering losses.

Based on behavioral analysis of investors' excessive confidence, Daniel, Hirshleifer, and Subrahmanyam (1998) point out that investors tend to overreact to private information signals and under-react to public information signals. The self-attribution bias and representative heuristic lend their support that when public information agrees with investors' private information, their confidence grows significantly. On the other hand, when public information does not agree with investors' private information, their confidence falls only slightly. They have shown that the positive return autocorrelation is a result of continuous short-term overreaction followed by some long-term correction. Their findings are consistent with short-term continuation and long-term reversal found by Balvers, Wu, and Gilliland (2000) in their study by using the national stock index data of 18 countries from 1969 to 1996. Easterwood and Nutt (1999) find that even professional analysts under-react to most negative information, but overreact to most positive information. Chan, Karceski, and Lakonishok (2000) lent their support for the behavioral thesis and against the rational asset pricing hypothesis based on their study for the period from 1984 to 1998. Haugen (1999) argues that rational efficient market is not consistent with empirical findings on abnormal stock returns for stocks with high current earnings yields, high book-to-price ratios, short-term price momentum and long-term reversal, excessive price volatility, and January effect, to name a

few. Hirshleifer (2001) and Barberis and Thaler (2003) provide excellent comprehensive survey on major issues and findings of behavioral finance.

The irrational behaviors of market participants are detailed in Shiller (2000). His book was right on target when it was published just before the most serious market collapse, particularly the technology stocks, since the Great Depression. He listed twelve major factors, i.e., the arrival of the Internet, triumphalism and the decline of foreign economic rivals, cultural changes favoring business successes, capital gain tax cuts, baby boom and its perceived effects on the market, increasing business news reporting, analysts' optimistic forecasts, increasing pension contribution, the fast growing mutual funds, disinflation, more discount brokers and day traders, and increasing gambling opportunities all contributing to the irrational exuberance of the most recent bull market from August 1982 to early 2000. Many Wall Street analysts became not only too optimistic about their forecasts but the promoters of stocks they followed. For example, based on Thompson Financial/First Call as of November 2001 sell recommendation went up from a merely 0.9 percent a year ago to only 1.6 percent of all ratings. Since the market collapse in 2000 we have witnessed the publicity of the accounting irregularities, conflict of interests between analysts and their affiliated investment banking firms, problems of corporate governance, and the passage of the Sarbanes-Oxley Act of 2002. All these point to the irrationality of many market participants and quite a few corporate executives in the real financial market places. In brief, the empirical findings from behavioral finance studies clearly show that investors in the stock markets behave more than bounded rational and far beyond the assertions of EMH.

From a recent CFA magazine's roundtable discussions Trammell (2006, p. 31) succinctly summarized the key points as: "Like hilltop citadels, theories about rational behavior are conspicuous targets for both practitioners and professors of finance. Although defenders of rationality declare that no wall has been breached, assailants do not consider themselves defeated. If anything, they are sharpening their swords and their numbers are multiplying. From analyst conferences to academic papers, neoclassical finance is under siege." According to Harrington (2006) behavioral finance have been put into practice such as Fuller & Thaler Asset Management having US$4 billion under management with Richard Thaler, a leading behavioral finance proponent, as a principal and Daniel Kahneman, a Nobel laureate on the board of directors.

A related but less known new breed is identified as evolutionary finance mainly in Europe at the present time. According to Professor Thorston Hens, behavioral finance focuses on individual mistakes and not as much to the markets. On the contrary, the evolutionary finance targets at asset management and takes an integrated view of interactions among strategies. Evolutionary finance can be applied to both individuals and institutions such as hedge funds and delegated asset management. The traditional CAPM and mean-variance theory were based on cross-sectional returns, whereas evolutionary finance is based on time series and dynamic systems (Grotheer, 2006).

Finally, based on interviews with 118 traders and trader managers in 1997 and 1998 in London, Fenton-O'Creevy et al. (2005) find that traders are very different in background, personality, and risk considerations. They are all subject to various degrees of cognitive biases. They are emotionally involved in their work, and they trade on the basis of beliefs and hunches. Arbitrage is not risk free and irrational prices in the market may persist. Professional traders are susceptible to biases and illusions and they are major contributors to noise trading. Emotion is an essential and perceptible thread connecting market movements. Formal financial economic theory and models may provide basic background for traders' works, they cannot serve as a guide for action. "Traders' success depends not simply on their own skills and knowledge, but also on their social capital: their membership of networks and the nature of the trust and reciprocity within those networks" (p. 200). Traders are in general risk averse, introverted, and conservative.

5. Neural/Medical Finance and Adaptive Market Hypothesis

Over the past half a century economics has made significant progress and contribution by systematically applying scientific methods such as mathematics, physics, statistics, and econometrics to economic analysis. Finance as a late comer has basically followed the same approach and made significant contributions to the development of capital asset pricing model, arbitrage pricing

model, option pricing models, and diversified financial innovations. These mainstream economic and financial analysis and applications will continue to develop new theories and models and will be modified and affected by the increasing attention paid to bounded rationality and behavioral finance. As a result of the development of behavioral finance, the so-called "abnormalities" of the financial markets pointed out previously from the EMH viewpoint will eventually be considered as normal market phenomena. As new technology improves rapidly, our understanding of human decision making process progresses gradually, and our computing capability increases tremendously, the financial markets will embrace neurofinance as a helpful new development.

Neurofinance analyzes financial markets by applying neurotechnology to observe and understand the trading behaviors of market participants. The major goals of neurofinance are to gain better understanding of financial markets by identifying some physiological traits affecting trading behavior and trading results, to associate these traits with trading results, and to develop methods, technology, and proper training to improve trading performance. Neurofinance assumes that market participants have different psychophysiological make-ups which affect their ability to make rational decisions and their performance in investing. The difference between behavioral finance and neurofinance is that the former investigates how people act and interact in the process of making financial decisions and interpret these actions based on established psychological concepts and theories, whereas the latter examines why and how these behaviors occur based on the observations on people's brain and hormonal activities. Closely related neuroeconomics seeks to understand the physiological basis for making economic decisions, while neurofinance concentrates more on financial markets and activities of market participants.

The reason I call neural finance as medical finance is because brain function depends on the health of the brain itself and the impact of drugs. For example, brain lesions in the orbital frontal cortex, a processing center of the reward system, may result in abnormal financial decision-making. Acute mania tends to result in euphoric mood and excessive risk taking. Treatments for mania include antipsychotic medications that block or limit the neural stimulation caused by dopamine release. Melancholic depression may cause excessive sleepiness and chronic risk aversion. Anxiety is characterized by excessive risk perception and hyper vigilance and may lead to panic selling, impulsive overtrading or avoidance of financial markets. Some executives are rumored to take Prozac to allow them to look beyond perceived threats and decide quickly without ruminating and stay optimistic during stress. Amphetamines can increase brain's extra cellular concentration of dopamine. Several medications can directly change risk/return perceptions in behavioral experiments. Common blood pressure medications and beta-blockers may reduce people's aversion to potential financial losses. In addition to the mentioned medications, investors may also need some psychological support to avoid the common cognitive, behavioral, and affective biases. Being flexible and knowing the human fallibility, investors will minimize denial, disappointment, and anger when they realize they have made wrong decisions.

Investors' financial performance tends to suffer when they are emotionally reactive and have poor impulse control. Psychology, physiology, and neurology are intertwined in some rather complex fashion. In recent years with the help of recently developed technology and equipment such as positron emission tomography (PET) and magnetic resonance imaging (fRMI), some researchers are able to conduct controlled experiments to investigate the brain activities and psychophysiological characteristics when investors or traders are making financial decisions. Lo and Repin (2002) observe, record, and analyze the relationship between physiological characteristics such as skin conductance, cardiovascular data, electromyography data, respiration rate, and body temperature, and real-time financial decision making process of 10 highly trained professional traders. They find that emotional responses are an important factor in the real-time processing of financial risk. They find statistically significant differences in mean electrodermal responses during transient market events relative to no-event control periods, and statistically significant mean changes in cardiovascular variables during periods of heightened market volatility relative to normal-volatility control periods.

Kuhnen and Knutson (2005) used the event-related fMRI to examine if anticipatory neural activity may predict optimal and suboptimal financial decision making. They distinguish two different types of deviations from the optimal investment strategy of a rational risk-neutral agent: one is risk-seeking mistakes and the other is risk-aversion mistakes. They find that "nucleus accumbens

activation preceded risky choices as well as risk-seeking mistakes, while anterior insula activation preceded riskless choices as well as risk-averse mistakes" (p. 763). Their review of brain imaging studies shows that when people anticipate physical pain, aversive visual stimuli, risky choices, or anxiety, anterior insula is activated. On the contrary, when people anticipate monetary gain, the nucleus accumbens of the ventral striatum are activated. They also indicate that anticipatory neural activation may also promote irrational choice. All these real-time actual experiments and observations on investors and traders will help us understand better why and how they make investment and trading decisions. Neurofinance may also help investors determine optimal investment strategies to meet their investment goals and improve their investment performance. With suitable control of investors' affects and emotion the financial markets may become less volatile.

The adaptive market hypothesis (AMH) introduced by Lo (2004, 2005) tries to incorporate some aspects of evolutionary biology, neuroscience, physiology, psychology, and sociology into economic and financial market analysis to examine the actual decision process made by market participants. The recent advances in fMRI and PET scan have enabled neuroscientists to see the actual brain activities (Restak, 2003). Lo believes the application of evolutionary principles to financial markets is especially promising. The AMH is parallel to the recent development in evolutionary game theory, evolutionary economics, and the general economics as a complex system. Indeed AMH is built upon the idea of Wilson's (1975) sociobiology and Simon's (1955, 1982) bounded rationality. The process of human optimizing behavior is through trial and error, and the decision making process is based on the past and present experience and the best guess as to what might be optimal. Decision makers then learn by the positive or negative feedbacks from the outcomes. Finally they develop some heuristics to solve the problems or any investment challenges they face. As the economic or market conditions change, the old heuristics they developed are no longer appropriate and as they observe some behavioral biases, they then have to adjust and develop new heuristics. Since market conditions are subject to continuous and abrupt changes, market participants will continue to adjust and adapt.

According to Lo (2004, 2005), the behavioral biases of market participants are frequently observed. For example, as market conditions change and the profit and loss opportunities follow some cyclical patterns, investors shift from value to growth strategies and vice versa. Even fear and greed are the result of evolutionary forces with adaptive characteristics. Some results from recent research in cognitive neurosciences and economics show some significant link between human decision-making and emotion. One conspicuous example is the boom and bust of high tech stocks from late 1990s to 2002. Since 1975 research studies on the relation between emotion and cognitive processes and the impact of mood on memory have increased significantly (Hunt and Ellis, 1999). The findings from cognitive psychology show that emotion affects not only people's memory, but more importantly people's judgment. When people are making investment decisions under uncertain and ever changing conditions in the global financial markets, it is reasonable to expect that investors will deviate from rationality and modify constantly their decisions by learning from their mistakes. In addition, the increasing global financial market competition and the great rewards to the fittest traders imply that the Darwinian selection of the survival of the richest is at work. The EMH is the steady-state limit while the AMH is the actual adaptation process toward the final equilibrium. In the fast changing global financial markets, before any steady-state equilibrium is reached, the markets are already moving toward another new equilibrium. In other words, we may only observe the AMH at work but never experience the EMH of the true equilibrium in the actual financial markets.

According to AMH the risk-return relationship is likely to change over time and is path-dependent as market conditions change frequently. Similar to what was pointed out by Shleifer (2000) AMH implies that arbitrage opportunities in financial markets will arise from time to time. Gathering and diffusion of information enhance market efficiency, but if there exist no arbitrage opportunities, there will be no incentive for information gathering and diffusion. AMH also implies that investment strategies and portfolio performance will change over time. Even though mutual fund managers as a whole may not consistently outperform the market over long period of time as pointed by Malkiel (2003), many professional fund managers such as Peter Lynch and William Gross do outperform the market over a prolong period of time. Indeed, switching from

value investing to growth investing and vice versa over time is an excellent demonstration of market participants' adaptation to the changing market conditions. Varying asset allocations, adjusting hedging strategies by different derivative securities, and sector rotation investments are some of the examples of investors' adaptation to the changing market conditions.

6. Recent Evidence of Highly Correlated and Volatile Markets

Robert Shiller has run the rolling 60-month first-order autocorrelation coefficients based on monthly S&P composite returns from January 1871 to April 2003. The coefficients show clear cyclical pattern of positive autocorrelation with some exceptions of negative autocorrelation occurred in the mid and late 1950s (Lo, 2004, p. 25). Based on the NASDAQ and S&P 500 indexes from January 1971 to December 2004, I find both indexes are highly and positively correlated. For NASDAQ the autocorrelation coefficients are positively and significantly different from zero for 23 months and stay positive but insignificant for many more months for the entire period and from January 1971 to December 1990. For the shorter time period from January 1991 to December 2004 the autocorrelation coefficients are positively and significantly different from zero for 12 months, and they turn negative but insignificant at lag 42. One major reason why for shorter time period the coefficients are significant for not as many months is the fact that the standard error of autocorrelation coefficient is cumulative and inversely related to the square root of the number of observations. When autocorrelation analysis is applied to the S&P 500 index for the entire period, the autocorrelation coefficients are positive and significant for 28 months and stay positive for 60 months. For the period from January 1971 to December 1990, the autocorrelation coefficients are positive and significant for 20 months and stay positive but insignificant for 50 months. From January 1991 to December 2004, autocorrelation coefficients are positive and significant for 14 months, but turn negative and insignificant at lag 45. This autocorrelation analyses show that stock markets are significantly and positively correlated for about one to two years. These recent findings are consistent with the observations of short-term momentum and long-term reversal pointed out previously.

Finally, I analyze the daily and monthly returns for S&P 500 and DJIA from January 3, 1971 through December 30, 2005, and NASDAQ from February 4, 1971 through December 30, 2005. Furthermore, I also divide the whole period into 7 sub-periods of 5 years each, and the great volatility of either the monthly returns or the daily returns appears not very consistent with the EMH but it tends to support the behavioral argument. For examples, for S&P 500 the highest monthly return was 16.30 percent and the lowest was negative 21.76 percent. The greatest daily return was 9.10 percent, and the lowest was negative 20.47 percent. Judging by the coefficient of variation of monthly and daily returns, the most volatile period occurred between 2001 and 2005 with CV of 427.07692 for monthly returns and 15.35545 for daily returns followed by the sub-period of 1971-1975 with CV of 43.61224 for monthly returns and 7.30245 for daily returns. For NASDAQ the highest monthly return was 18.02 percent and the lowest was negative 37.43 percent, while the highest daily return was 14.17 percent and the lowest daily return was negative 11.35 percent. For monthly returns the greatest volatility happened between 1986 and 1990 with CV of 65.85507 followed by negative 20.96421 happened between 2001 and 2005. The greatest daily return volatility for NASDAQ occurred between 1971 and 1975 with CV of negative 11.38095 followed by the sub-period of 2001-2005 with CV of 7.44083. As for DJIA the highest monthly return was 14.41 percent and the lowest was negative 23.22 percent. The highest daily return was 10.15 percent and the lowest daily return was negative 22.61 percent. The greatest volatility for monthly return happened between 1971 and 1975 with CV of 7.28360 followed by 6.78657 happened between 2001 and 2005. For daily return the most volatility occurred between 2001 and 2005 with CV of 5.45454 followed by the sub-period of 1971-1975 with CV of 3.95349. Stock market price indexes and returns were positively and significantly affected by transaction volumes for both daily and monthly data and for all three different market indexes.

The international stock market daily and monthly indexes were also examined for different time periods. For Japan, the data were from January 5, 1984 to April 25, 2006; Hong Kong, December 1986 to April 28, 2006; Singapore, December 28, 1987 to April 28, 2006; Mexico, November 8, 1991 to April 28, 2006; Taiwan, July 3, 1997 to April 28, 2006; and Canada, January 3,

2000 to April 28, 2006. The whole period and every five year sub-periods for every country were analyzed. Mexico had the lowest volatility with coefficient of variation being all below one. Taiwan had the highest volatility with coefficient of variation ranging from -7.92 to 12.96. Hong Kong, Singapore and Japan's volatility are somewhere in between. The relative lower volatility of market indexes of these countries compared to the U.S. market indexes is likely due to regulation and restrictions rather than higher efficiency in those markets. Finally, in every market transaction volume had positive and significant impact on both price and return.

7. Conclusion and Direction for Future Research

This paper has pointed out that the actual financial markets tend to deviate from the three basic assumptions underlying the traditional efficient market hypothesis. The Nobel Prize winning psychologist, Herbert Simon, made path-breaking contribution by applying bounded rationality to economic analysis and models. More recently, another psychologist, Daniel Kahneman, who received the Nobel Prize in economics for his contributions, applied the prospect theory to economics and financial markets and has contributed to the rapid development of behavioral economics and finance in the past two decades. Even the widely proclaimed information efficiency underlying the fundamental EMH was questioned by Grossman (1976) and Grossman and Stiglitz (1980) who believe that in the real world there exists no perfectly efficient information market. However, no one can deny the significant contributions made by the thorough analysis of perfect competition and general equilibrium in economics and various asset pricing models along with EMH in finance. The behavioral finance has contributed to our better understanding of actual investors' behavior and real market practices over the past 25 years and is expected to make significant further progress. All these theories have contributed to help investors make better investment decisions in the very complex and complicated financial market places. The newly introduced adaptive market hypothesis appears to be promising in integrating the traditional EMH, bounded rationality, evolutional socio-biology, neuroscience, physiology, psychology, and behavioral finance. In addition, with the rapid improvement in information technology, the deregulation across nations, the increasing global economic and financial market integration, some financial economists someday may develop some comprehensive and testable models incorporating quantitative, qualitative and other significant factors from various fields just mentioned. The expected rapid new development in the above mentioned fields is expected to improve the efficiency and predictive power of investors' behavior and the entire financial markets in the future. Since neural/medial finance and AMH are at its infant stage of development, much more theoretical analysis and empirical testing are needed. This is the direction of our future research. Indeed, neurofinance and AMH are expected to adapt to the fast development and breakthroughs of all related fields. At this stage it is too early to predict the future potential and the limits of neural/medical finance and the AMH.

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