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Equity Research

Americas | U.S. Investment Strategy | September 11, 2000

It's the Ecology, Stupid

How Breakdowns in Market Diversity Can Lead to Volatility

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Volume 11

- Understanding volatility requires insight into the interaction between market actors with different investment styles. This is in contrast to economic theory, which assumes homogenous agents.
- Heightened volatility can result when some agent types either willfully opt out of the market activity, or trade in a manner that reflects the decision rules of another class of participants.
- Volatility resulting from a breakdown in the ecology of investors is a permanent feature of markets. However, today's markets bear some peculiar features that make them more prone to excess volatility.
- Growing evidence accumulated from market models of heterogeneous agents should prompt investors to approach the dated market efficiency debate with a fresh perspective. Recognizing the trading features associated with a financial ecology breakdown can lead to profit opportunities.

Introduction

". . . imagine market quotations as coming from a remarkably accommodating fellow named Mr. Market, who is your partner in a private business. Without fail, Mr. Market appears daily and names a price at which he will either buy your interest or sell his. Even though the business that the two of you own may have economic characteristics that are stable, Mr. Market's quotations will be anything but. For, sad to say, the poor fellow has incurable emotional problems."

—Warren Buffett paraphrasing Benjamin Graham[1]

Every day countless investors, through the buying and selling of securities, make statements about the value of businesses in the marketplace. From this chaotic maelstrom emerges a price tag for every public company. At any point, the prevailing price reflects the best collective statement about what an individual security is worth. The characteristics of this complex adaptive system—known simply as "the market"—are heavily scrutinized, and highly contentious.[2] And though the views of academics and practitioners are frequently at odds, one thing is certain: it's very difficult to consistently beat the market.[3]

Benjamin Graham's metaphor of Mr. Market is meant to illustrate the reality of how moment to moment price swings can depart from "fundamental" value. While most active investors are aware of the mechanics surrounding securities trading, few fully understand the degree to which prices pay a concession to these mechanics.

In an ideal world, there are no transaction costs. Information is free, available to all market participants, and investors agree on the implications of that information.[4] Economist Ronald Coase astutely observed that the dismal science often misses the mark due to the fact that "their theoretical system [does not] take into account a factor which is essential if one wishes to analyze the effect of a change in the law on the allocation of resources. The missing factor is the existence of transaction costs."[5] Trading securities involves matching buyers and sellers within a particular market structure. What's important is that this market structure itself influences price formation.

Illiquidity is chief among the anomaly-causing frictions. Liquidity is an all-encompassing term that captures popular concepts like supply, demand, order flow, and market depth. Though strictly defined as the ease with which an asset can be turned into cash, it is best understood as the cost of immediacy. That is, it's the cost of getting what you want when you want it. Illiquidity is best viewed as an important and large cost of transacting. For example, transaction costs include both the bid-ask spread and market impact—where the very act of trading changes the stock price.

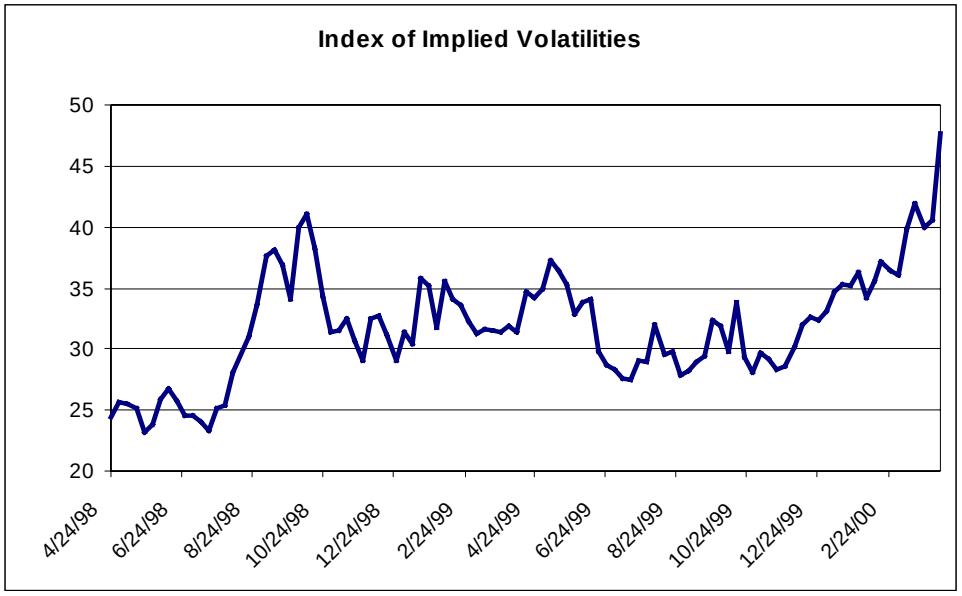
While the effect of liquidity on stock prices has been studied in detail, a less well-known but equally powerful influence on prices is market ecology. Market ecology deals with the composition of the underlying agents that set prices. While liquidity is highly correlated with the *number* of market participants, market ecology is a direct function of the *type* of market participants in the system. More directly, the types of investors in the market, and their degree of participation, has a significant influence on how well markets function.

This issue of ecology is important not only because it lends insight into how markets function, but it also provides a basis for potential moneymaking opportunities. For example, a commonly held belief of market observers is that the steep rise in the number of day traders over the last couple of years has led to increased market volatility and a diminution of market efficiency. A deeper understanding of market ecology helps illustrate why this concern is misplaced.

Market Mechanics

U.S. equity markets have become more volatile over the past two years.[6] Despite consensus regarding the increase in volatility, there is little agreement about its causes.[7] One logical explanation is based on the profound shift in the economy. The economy is transitioning to one dominated by intangible rather than tangible assets. This has engendered greater uncertainty, and has called into question the competitive position of virtually every business.

Figure 1
Average Market Volatility for 18 Indexes



Source: Bloomberg and CSFB analysis.

Although numerous studies corroborate the upward trend in volatility documented in Figure 1, it's incorrect to assume that volatility is at historic highs. In fact, most studies of market volatility over the last century conclude that the recent period of volatility is hardly an aberration.[8]

The most recent surge in market volatility, between mid-October 1999 and mid-April 2000, came at a time when the number of equity trading accounts rose 15%.[9] According to SIA member firms, these newcomers opened online and margin accounts in record numbers. The seeming daily gyrations in the Nasdaq composite coupled with margin debt soaring to levels not seen since 1929 convinced many market watchers that these "new wave" investors were the "cause" of all the volatility.[10] We believe this commonly held notion is incorrect and reflects an important misunderstanding about the nature of securities markets.

Volatile Views on Volatility

Volatility has many sources. These include the influx of new, unanticipated information into the market, an alteration in market structure, and the changing risk tolerance of investors. In addition, changes in macroeconomic policy can have a profound effect on volatility.

But there is another significant and generally unexplored dimension of volatility. It has to do with the "ecology" of investors. The word ecology comes from biology, where it is used to refer to the ways in which living things interact with one an-

other and with their surroundings. How investment "species" interact (i.e., market participants with particular investment styles) has a direct bearing on price volatility. The balance of this report focuses on this largely unexplored issue.

Ecology

For the last two centuries, the machine has been the dominant metaphor for describing the economy. Increasingly, leading thinkers accept the view that a capitalist economy is best understood as a living ecosystem, complete with competition, specialization, cooperation, exploitation, learning, and growth.[11] In his groundbreaking book, *Bionomics*, Michael Rothschild argues that the analogy between ecosystem and economy does not need to be perfect in order to be powerful. The central concept is that biological and economic life are self-organized, and operate in much the same fashion. A parallel relationship exists between an ecosystem based on genetic information and an economy derived from technical information.[12]

Figure 2
Interacting Species Interacting Strategies

Biological Ecology	Financial Ecology
species	trading strategy
individual organism	trader
genotype	functional representation of strategy
phenotype	actions of strategy (buying, selling)
population	capital
external environment	price and other informational inputs
niche	a possible flow of money
selection	capital allocation
mutation and recombination	creation of new strategies

Source: Doyne Farmer, "Market Force, Ecology, and Evolution."

As Figure 2 illustrates, it's not just the general economy that can be understood in this way, but securities markets as well. The relationship between species interacting in an ecosystem on the basis of genetic information mirrors that of investors in the stock market interacting on the basis of evolving valuation strategies.

Markets Are Complex

We believe that securities markets are best understood as complex adaptive systems. [13] A complex adaptive system can be described in three steps. First, there are lots of agents, each operating with their own decision rules. Next, the interactions between the agents become the basis of "emergence"—the aggregate becomes more complicated than the sum of the parts. Finally, a "meta-system" is created that has distinct characteristics.

Agents exist in a variety of types, each with their own characteristics. They employ their strategies—conditional action patterns that indicate what should be done under certain circumstances—by interacting with other agents.[14] Each agent uses success criterion to attribute credit in selecting relatively successful or unsuccessful strategies. This in turn leads to a process that increases or decreases the frequency of various types of agents or strategies.[15]

In stock market language, "agents" are investors. Their "strategies" are investment styles—growth, value, momentum, etc. Their scorecard is performance, either absolute or versus a benchmark. And because of the market's never-ending change, various investors succeed and fail.

We take a closer look at these concepts using the framework devised by Robert Axelrod and Michael Cohen in their book, *Harnessing Complexity*.

- *Variation.* Variety represents the diversity of agent types within a population or system. Variation provides the raw material for adaptation. The premise of the complex adaptive system (CAS) approach is that agents are diverse. The default assumption is that this variety within the population matters. In equity markets, agents mostly have "local" information. The result of combining the knowledge of the individual participants is that the whole knows more than the parts. Mainstream economics maintains that all economic players are homogenous: not only do agents value information in the same way, but they need the same information and react to it accordingly. This tenet has profound implications.[16] Standard economic theory should lead to limited trading activity, which isn't what we see in markets. It is precisely the variation among the agents and their strategies that provides for a robust market environment.

- *Interaction.* Interaction between agents creates many of the interesting events in a system. In an equity market, the interactions of financial agents are mediated through a single variable—the stock price. Each trading strategy influences the price. The price, in turn, influences each trading strategy. Recurring regularities of contact occur among types within a system. In equity markets this contact is dictated by the market structure.

- *Selection.* Selection leads to an increase or decrease in the various types of agents and strategies. Performance measures define success. Success or failure often leads to new or refined strategies. Instead of categorizing investing strategies into broad groups, we find that it's useful to view them along a continuum. At one end are the "value," or fundamental strategies, based on some subjective view about the difference between a security's intrinsic worth and its price. Strategies that focus on price history, either to follow trends or to augur future movements, occupy the other pole. Strategies along the continuum are thus defined by their proximity to subjective assessments of value versus market-watching behavior. At any time, the current distribution of valuation and trading strategies reflects the relative success of each strategy. And most "changes" are refinements to existing market strategies, rather than wholesale shifts to another strategy.

We suggest turning classic economic theory on its head. Instead of assuming that all investors have equal access to information, evaluate it in the same fashion, and have the same goals and time horizons for investment, we take the opposite tack. As proof we offer up the market itself![17] Trading goes on precisely because all investors are not equal in their access to information or their interpretation of that information. Trading, and the differences of opinion that it reveals, is essential for maintaining liquid markets.

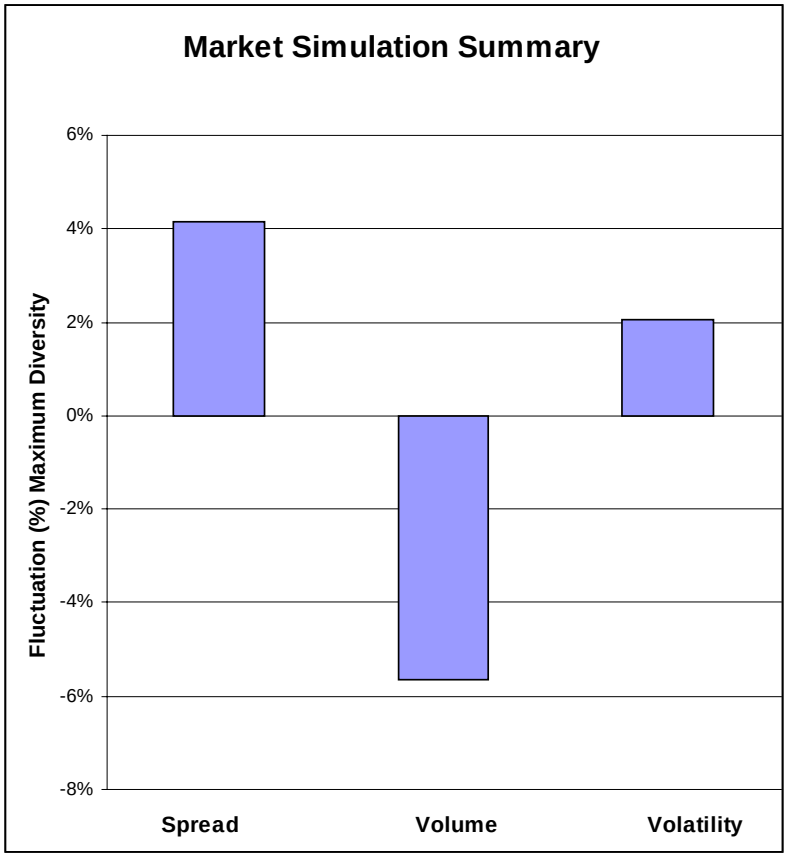
In professional golf circles, they say that every shot makes someone happy. Similarly, in the market there is a buyer for every seller. However, buyers and sellers do not necessarily pair off because their views on the prospects for the company are antipode. Often, it is for altogether different reasons: portfolio balancing, capturing an uptick on a trade, or a multitude of other reasons. The challenge is to model the market in its full diversity, in an effort to gain some insight into how the various agents contribute to prices and the inevitable swings that the market witnesses every day.

The Model

We developed a computer simulation of real-time stock trading, complete with agents that have different market strategies.[18] In developing the model, we focused on creating agents that looked like actual market participants.

As a result, three investor categories emerged: technicians, fundamentalists, and network traders. Fundamental investors are further divided into four subcategories, and all six types of agents buy and sell a single stock. A running "valuation scorecard" changes to reflect new information events that are imported into the market. All agents submit orders to buy or sell to the specialist (who maintains a book of orders) based on the sensitivity of their respective valuation metrics. The submitted trades establish a market price. This market price is recorded over time. At the end of the simulation, the average bid/ask spread, average volume, and volatility can be documented. In addition, the stock price at each transaction is written to a file. The results after roughly 500 simulations were combined, and appear in Figure 3.

Figure 3
Market Simulation Conclusions



Source: CSFB analysis.

The three plots represent the combined data for all the scenarios with the least amount of financial actors (the least diversity and most homogeneity). The percentage amounts indicate the spread between these runs and the combined data runs for all the scenarios with the greatest diversity in financial actors (most diversity and least homogeneity). As can be seen, as the composition of market agents became less diverse, spreads increased, volume dropped, and volatility increased.

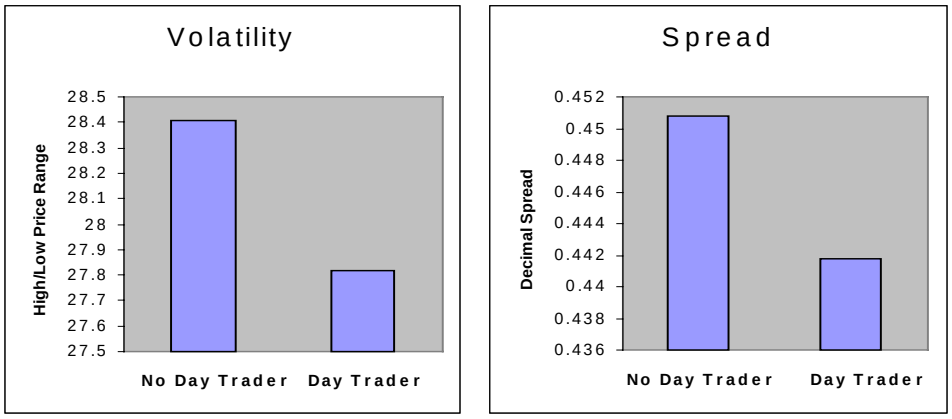
Conclusions

The ability to view the interaction of faithfully represented multiple agent types leads to valuable insights about how markets function. This is especially true when compared to unrealistic models of homogenous agents. Our model clearly shows that active participation by a diverse group of financial agents leads to less volatility and more structural efficiency. The implications of this research are worth examining in closer detail.

Day Traders

One group of agents cannot be held responsible for excessive market volatility. Understanding volatility requires understanding the interaction between multiple agent types. Heightened "market-structure" volatility requires that some agent types either willfully opt out of the market activity or trade in a manner that reflects the decision rules of another class of agents. These scenarios result in effective homogeneity, which creates rigidity and leads to endogenous volatility.[19]

Figure 4
No Day Traders



Source: CSFB analysis.

Figure 4 represents summary data for eight market trials. Four involved a market with all the agents outlined in the model. The other four excluded day traders from the group entirely. Without the participation of day traders, the bid ask spread widened in every trial. In addition, the volatility of the market (as indicated by price dispersion through one trading cycle) increased in every trial where the much-maligned day trader was absent. This pattern was observed in 44 additional trials, where we actively modified the relative composition of fundamental agents. This result reflects trials where day traders consisted of as much as 15% of the total agents in the market—a figure roughly five times the amount tallied by the Securities & Exchange Commission in a recent report.[20]

Ecological Volatility

Volatility resulting from a breakdown in the ecology of investors is a permanent feature of markets. However, the markets of today bear some peculiar features that might make them more prone to excess volatility from this particular feature of market structure. The information revolution raises a fundamental question about the ability of social networks to maintain their diversity. Drawing on "small world" network research, some observers conjecture that we might be crossing a threshold where increased interaction among previously distant agents leads to a radical decrease in global diversity.[21] Greater contact with "distant others" allows for information (or rumor) to travel faster through the system.

In the context of markets, naive strategies can gain widespread currency (such as buying on stock splits or dips). These strategies are then reinforced by a growing number of information channels, blunting needed variety. Two crucial elements of complex adaptive systems are nonlinearity and critical points. Nonlinearity is the idea that the output of a system need not necessarily be proportionate with the input of the system. In mathematical terms, complex dynamical systems can go through "critical points" where a small-scale stimulus can lead to sudden, explosive, large-scale effects.

Researchers have modeled this behavior for stock markets. Guided by these models, they conclude that crashes can result from the slow buildup of long-run correlations, leading to a collapse in one critical instant.[22] It is important to note that a crash occurs when a large group of agents simultaneously place sell orders. So a crash actually results when "order" wins out (i.e., when everybody has the same opinion, or revealed preference). Interestingly, this is in contrast to the "chaos" and flurry of activity that occurs in the wake of a crash.

What is the mechanism for this massive, but uncoordinated, homogeneous behavior? The answer lies with the structure of social networks. Models of such behavior show that spontaneous local imitation (small clusters of traders influencing each other) can quickly propagate over a network, leading to global cooperation. When we consider the ecology of investors in conjunction with this framework, it is clear that agents that typically form idiosyncratic opinions about intrinsic value (agents closest to this valuation pole) must either become uncertain about their forecasts and "drop out," or begin to swing toward market watching behavior. In either instance the result is the same: excessive volatility.

Beyond Efficiency

Think beyond market efficiency. The growing evidence provided by market models of heterogeneous agents prompts us to approach the dated market efficiency debate with a fresh perspective. While it's hard to be smarter than the market as a single actor in a complex adaptive system, Warren Buffett's insightful admonition regarding volatility becomes more pertinent than ever. "If you can manage the risk between your ears, then volatility truly becomes your friend."[23] That is, investors with a solid sense of intrinsic value—those long-term investors that stick to their cash flow guns and don't "drop out"—stand to gain from the additional buying opportunities presented in a volatile market environment. While identifying ecology breakdowns in equity prices is a difficult task, an understanding of how diverse financial agents interact and set prices can point to potential moneymaking ideas.

Endnotes

[1] "Chairman's Letter to Shareholders," Warren Buffett, *Berkshire Hathaway 1987 Annual Report.*

[2] For a full review of the debate see *Frontiers of Finance—Shift Happens*, Michael J. Mauboussin, Credit Suisse First Boston Equity Research, October 24, 1997.

[3] If the ability to beat the market is a measure of efficiency, then the market is definitely becoming more efficient. As Peter Bernstein notes in "Where, Oh Where, Are the .400 Hitters of Yesteryear?," *Financial Analysts Journal*, November-December 1998, pp. 6-14, excess returns since 1984 in both the top and bottom quintiles of general equity mutual fund managers returns have gotten smaller.

[4] "Efficient Capital Markets: A Review of Theory and Empirical Work*,"* Eugene Fama, *The Journal of Finance*, May 1970.

[5] "Notes on the Problem of Social Cost," Ronald Coase, *The Firm, the Market, and the Law*, summarizing the debate since his original presentation in *The Journal of Law and Economics*, Oct. 1960, 3, 1-44.

[6] "Volatility of NYSE Composite Index 1966-2000," *The New York Stock Exchange*; "Monetary Policy and Asset Price Volatility," Ben Bernanke, *National Bureau of Economic Research*, February 2000.

[7] "High Volatility: A Cautionary Tale," Frank A. Fernandez, *Securities Industry Association*, Vol. I, No. 4, May 31, 2000.

[8] See volatility charts for this century at http://schwert.ssb.rochester.edu/volatility2k.htm. Despite these findings there is strong evidence of a surge in firm-level volatility relative to market volatility over the last three decades. Much of this increasing volatility in individual stocks has been masked in the aggregate market numbers by a declining correlation in their price movements. See Malkiel et al., "Have Individual Stocks Become More Volatile," *National Bureau of Economic Research*, March 16, 2000.

[9] See report to SIA, May 2000, pp. 3-4.

[10] Examiners at the SEC even reviewed how day-trading activities fit within the current securities regulatory structure, as well as its impact on markets: http://www.sec.gov/news/studies/daytrep.htm#seciii.

[11] John Henry Klippinger III, *The Biology of Business: Decoding the Natural Laws of Enterprise*, October 1999.

[12] Michael Rothschild, *Bionomics: Economy as Ecosystem*, 1990, from the preface.

[13] *Frontiers of Finance—The Invisible Lead Steer*, Michael J. Mauboussin, Credit Suisse First Boston Equity Research, December 11, 1998; *Frontiers of Finance—Shift Happens,* Michael J. Mauboussin, Credit Suisse First Boston Equity Research, October 24, 1997.

[14] "Asset Pricing Under Endogenous Expectations in an Artificial Stock Market," W. Brian Arthur, John Holland, Blake Lebaron, Richard Palmer, Paul Taylor, *The Economy As An Evolving Complex System II*, Santa Fe Institute, 1997.

[15] Robert Axelrod; Michael D. Cohen*, Harnessing Complexity: Organizational Implications of a Scientific Frontier*, May 2000, pp. 52-53.

[16] Some of these are discussed by Edgar Peters in, *Patterns in the Dark: Understanding Risk and Financial Crisis with Complexity Theory*, John Wiley 1999, pp. 83-85.

[17] Peter Bernstein argues the same idea forcefully in "Why the Efficient Market Offers Hope to Active Management," *Journal of Applied Corporate Finance*, Summer 1999.

[18] We'd like to thank Christopher Maloney (our summer intern from Cornell's Ph.D. Physics program) for programming the market simulation. Additional details and the program itself are available to clients on request.

[19] Some commentators like Edgar Peters have asserted that most of the market crashes witnessed in the last 100 years occurred as a result of long term investors becoming uncertain about their ability to adequately value securities.

[20] http://www.sec.gov/news/studies/daytrep.htm#seciii.

[21] Duncan J. Watts, *Small Worlds*, Princeton University Press, August 1999.

[22] "Crashes as Critical Points," Anders Johansen; Olivier Ledoit; Didier Sornette, *International Journal of Theoretical and Applied Finance*, Vol. 3, No. 2 (2000) pp. 219-255.

[23] "Chairman's Letter to Shareholders," Warren Buffett, *Berkshire Hathaway 1982 Annual Report.*

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