FAJ
Financial Analysts Journal
Volume 68 • Number 2
©2012 CFA Institute

PERSPECTIVES

Adaptive Markets and the New World Order

(corrected May 2012)

Andrew W. Lo

In the wake of the financial crisis of 2007–2009, investors, financial advisers, portfolio managers, and regulators are still at a loss as to how to make sense of its repercussions and where to turn for guidance. The traditional paradigms of modern portfolio theory and the efficient markets hypothesis (EMH) seem woefully inadequate, but simply acknowledging that investor behavior may be irrational is cold comfort to individuals who must decide how to allocate their assets among increasingly erratic and uncertain investment alternatives. The reason for this current state of confusion and its strange dynamics is straightforward: Many market participants are now questioning the broad framework in which their financial decisions are being made. Without a clear and credible narrative of what happened, how it happened, why it happened, whether it can happen again, and what to do about it, their only response is to react instinctively to the most current crisis, which is a sure recipe for financial ruin.

In this article, I describe how the adaptive markets hypothesis—an alternative to the EMH that reconciles the apparent contradiction between behavioral biases and the difficulty of outperforming passive investment vehicles—can make sense of both the current market turmoil and the emergence and popularity of the EMH in the decades leading up to the recent crisis. Contrary to current popular sentiment, the EMH is not wrong; it is merely incomplete. Markets are well behaved most of the time, but like any other human invention, they are not infallible and they can break down from time to time for understandable and predictable reasons. By viewing financial markets and institutions from the perspective of evolutionary biology rather than physics,[1] I believe we can construct a much deeper and more accurate narrative of how markets work and what we can do to prepare for their periodic failures.

Andrew W. Lo is the Harris & Harris Group Professor at the MIT Sloan School of Management and chairman and chief investment strategist at AlphaSimplex Group, LLC, Cambridge, Massachusetts.

The Traditional Investment Paradigm

To understand the limitations of the traditional investment paradigm, consider its most common tenets: (1) There is a positive trade-off between risk and reward across all financial investments—assets with higher risk offer higher expected return; (2) this trade-off is linear, risk is best measured by equity "beta," and excess returns are measured by "alpha," the average deviation of a portfolio's return from the capital asset pricing model (CAPM) benchmark; (3) reasonably attractive investment returns may be achieved by passive, long-only, highly diversified market-cap-weighted portfolios of equities (i.e., those containing only equity betas and no alpha); (4) strategic asset allocation among asset classes is the most important decision that an investor makes in selecting a portfolio best suited to his risk tolerance and long-run investment objectives; and (5) all investors should be holding stocks for the long run. Collectively, these five basic principles have become the foundation of the investment management industry, influencing virtually every product and service offered by professional portfolio managers, investment consultants, and financial advisers.

Like all theories, these statements are meant to be approximations to a much more complex reality. Their usefulness and accuracy depend on a number of implicit assumptions regarding the relationship between risk and reward, including the following:

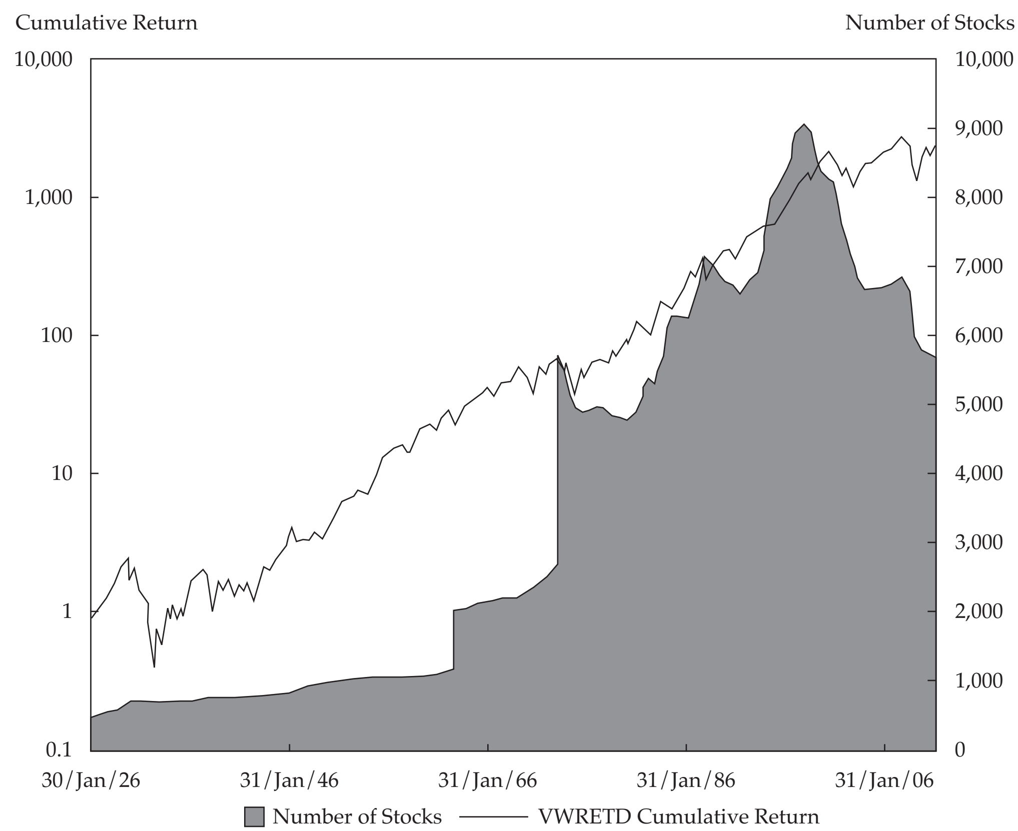
A1. The relationship is linear.
A2. The relationship is static across time and circumstances.
A3. The relationship's parameters can be accurately estimated.
A4. Investors have rational expectations.
A5. Asset returns are stationary (i.e., their joint distribution is constant over time).
A6. Markets are efficient.

Each of these assumptions can be challenged on theoretical, empirical, and experimental grounds, but all theories are, by definition, abstractions that involve simplifying assumptions. The relevant question is not whether these assumptions are literally true—they are not—but, rather, whether the approximation errors they generate are sufficiently small that they can be ignored for practical purposes. I propose that the answer to this question has changed over the past decade. From the 1940s to the early 2000s—a period of relatively stable financial markets and regulations—these assumptions were reasonable approximations to U.S. financial markets. However, the approximation errors have greatly increased in more recent years for reasons that we can identify, to the point where they can no longer be ignored.

Figure 1 provides a clear illustration of this perspective, in which the cumulative total return of the CRSP value-weighted stock market return index from January 1926 to December 2010 is plotted on a logarithmic scale (so that the same vertical distance corresponds to the same percentage return regardless of the time period considered). This striking graph shows that the U.S. equity market has been a remarkably reliable source of investment return from the 1940s to the early 2000s, yielding an uninterrupted and nearly linear log-cumulative-growth curve over these six decades. This period, which followed the Great Depression, should be called the Great Modulation because of the stability that characterized financial markets during this time.[2] While there were certainly some sizable ups and downs over this time span, from the perspective of an investor with a 10- to 20-year horizon, investing in a well-diversified portfolio of U.S. equities would have generated comparable average returns and volatility at almost any point during this 60-year period.

In such a stable financial environment, assumptions A1–A6 do yield reasonable approximations; hence, it is not surprising that the traditional investment paradigm of a linear risk–reward trade-off, passive buy-and-hold index funds, and 60/40 asset allocation heuristics emerged and became popular during this period. The more pressing issue at hand is whether the most recent decade can be ignored as a temporary anomaly—the exception that proves the rule—or if it is a harbinger of a new world order. There is mounting evidence that supports the latter conclusion.

Figure 1. Cumulative Total Return of CRSP Value-Weighted Stock Market Return Index, January 1926–December 2010



Notes: This figure provides a semi-logarithmic plot of cumulative total return of the CRSP value-weighted return index from January 1926 to December 2010 and a standard plot of the total number of stocks used in the index.

Sources: CRSP and author's calculations.

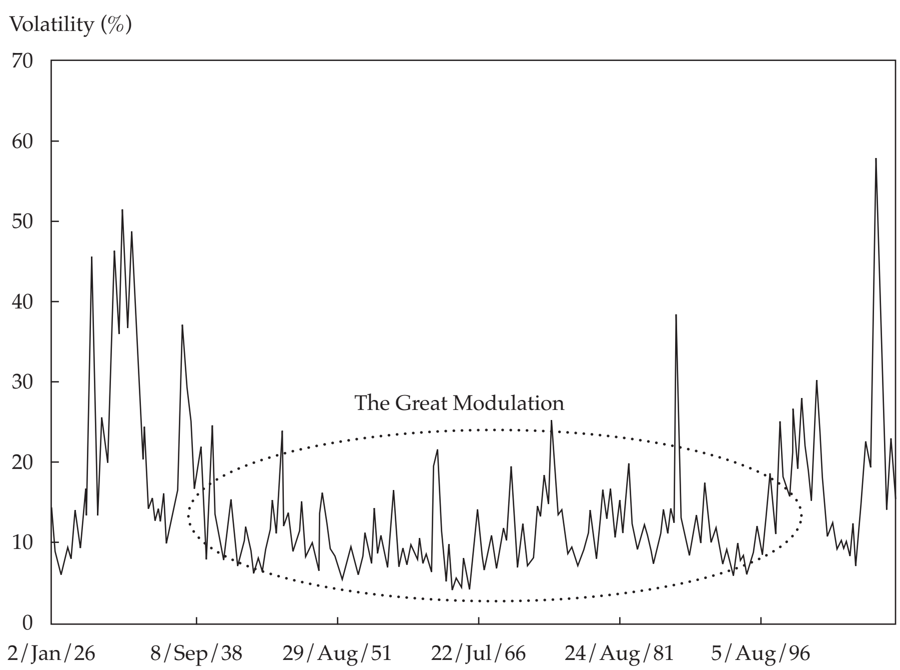
A New World Order

Although every generation of investors is likely to consider its own environment unique and special, with several unprecedented features and innovations, there are objective reasons to believe that the environment of the last decade is significantly different from that of the six decades prior. One obvious indication is volatility, something all investors have become painfully aware of over the past few years. **Figure 2** depicts the annualized volatility of daily CRSP value-weighted index returns over trailing 125-day windows, a measure of short-term volatility. This graph shows that the aftermath of the 1929 stock market crash was an extremely volatile period, which was followed by the decades of the Great Modulation, when volatility was considerably more muted. However, the highest-volatility period occurred not during the Great Depression but much more recently, during the fourth quarter of 2008 in the wake of the Lehman Brothers bankruptcy. Other market statistics—such as trading volume, market capitalization, trade-execution times, and the sheer number of listed securities and investors—point to a similar conclusion: Today's equity markets are larger, faster, and more diverse than at any other time in modern history. We are living in genuinely unusual times.

This pattern may well be a reflection of a much broader trend: population growth. **Figure 3** depicts the estimated world population from 10,000 BC to the present in logarithmic scale, and as with U.S. equities, this series also exhibits exponential growth (of course, the two phenomena are not unrelated).[3] Figure 3 shows three distinct periods of human population growth over the last 12 millennia: low growth during the Stone Age, from 10,000 BC to 4,000 BC; moderate growth from the start of the Bronze Age, around 4,000 BC, to the Industrial Revolution in the 1800s; and much faster growth since then. In 1900, the world population was estimated to be approximately 1.5 billion individuals; the most recent estimate puts the current world population at about 7 billion. Within the space of a century, we have more than quadrupled the number of inhabitants on this planet, and the vast majority of these individuals must work to survive and will, therefore, engage in some form of life-cycle savings and investment activity during their lifetimes. This naturally increases the required scale of financial markets as well as the complexity of the interactions among the various counterparties.

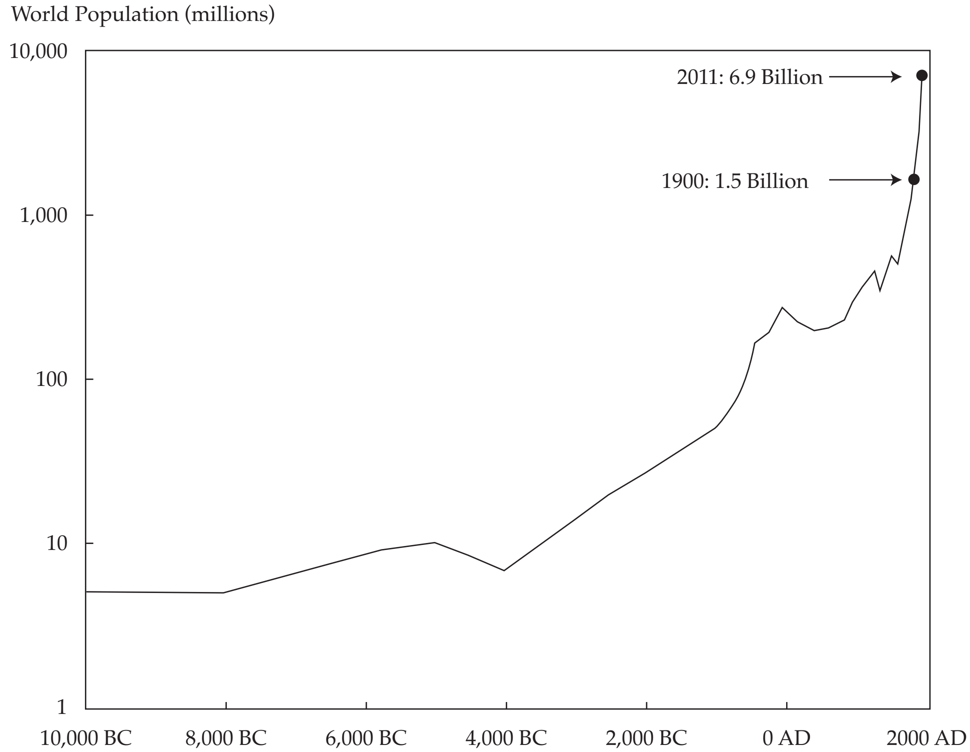
This dramatic increase in human population is no accident—it is a direct consequence of technological innovation that has allowed us to manipulate

Figure 2. Annualized Volatility of Daily CRSP Value-Weighted Index Returns over Trailing 125-Day Windows, 2 January 1926 to 31 December 2010



Sources: CRSP and author's calculations.

Figure 3. Estimated World Population from 10,000 BC to the Present



Sources: U.S. Census Bureau (International Data Base) and author's calculations.

our environment and natural resources to meet and, ultimately, greatly exceed our subsistence needs. Advances in agricultural, medical, manufacturing, transportation, information, and financial technologies have all contributed to this extraordinary run of reproductive success by *Homo sapiens*. These advances are largely the result of competitive economic forces, by which innovation is richly rewarded and through which recent innovations quickly become obsolete. This has led to a far different world today than the world of just a few decades ago. One of the most compelling illustrations of this difference is the pair of graphs in **Figure 4**, which display the population size, per capita GDP, and average life expectancy for various countries at two points in time: 1939 (Panel A) and 2009 (Panel B). In 1939, the United States—the large light-green circle in the upper-right range of Panel A—was in an enviable position, with one of the highest levels of per capita GDP and life expectancy among the major industrialized countries of the world and only a handful of close competitors.

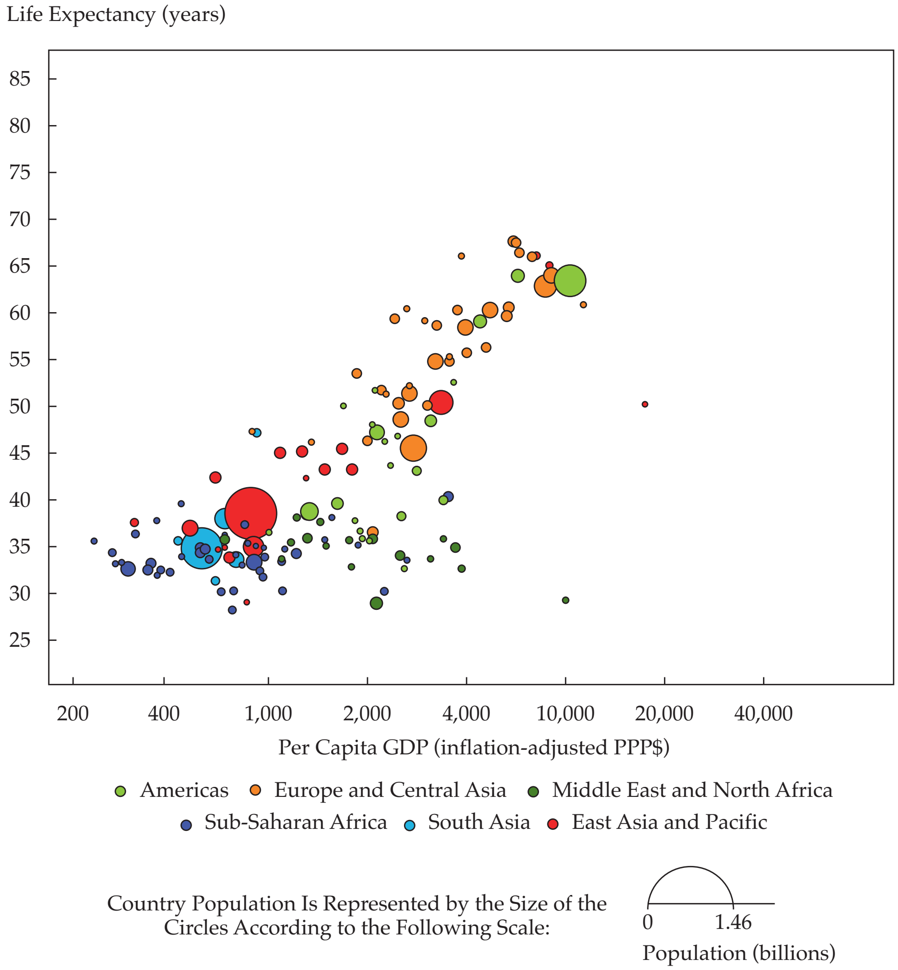
Panel B, however, tells a very different story: A mere six decades later, the United States is no longer the only dominant economic force in the global economy. It is now surrounded by many sizable competitors, including Japan (the largest red circle closest to the United States) and Europe (the many orange circles to the left of the United States). And the two most populous countries in the world—China (the largest red circle) and India (the largest light-blue circle)—have had an enormous impact on global trade patterns, labor supply, relative wages and production costs, foreign exchange rates, and innovation and productivity in just the last 20 years. Given these seismic economic shifts, is it any wonder that the dynamics of global financial asset prices, which must ultimately reflect the supply and demand of real assets, have become less stable in recent years? The Great Modulation is giving way to a new world order.

The Adaptive Markets Hypothesis

These large-scale economic changes and their political and cultural consequences are the ultimate reasons that assumptions A1–A6 have become less plausible in the current environment, and why financial market dynamics today are so different from what they were during the Great Modulation. Technological advances are often accompanied by unintended consequences, including pollution, global warming, flu pandemics, and, of course, financial crises. Financial technology in particular has been a double-edged sword. It has facilitated

Figure 4. Population Size, Per Capita GDP, and Average Life Expectancy for Various Countries, 1939 and 2009

A. 1939



(continued)

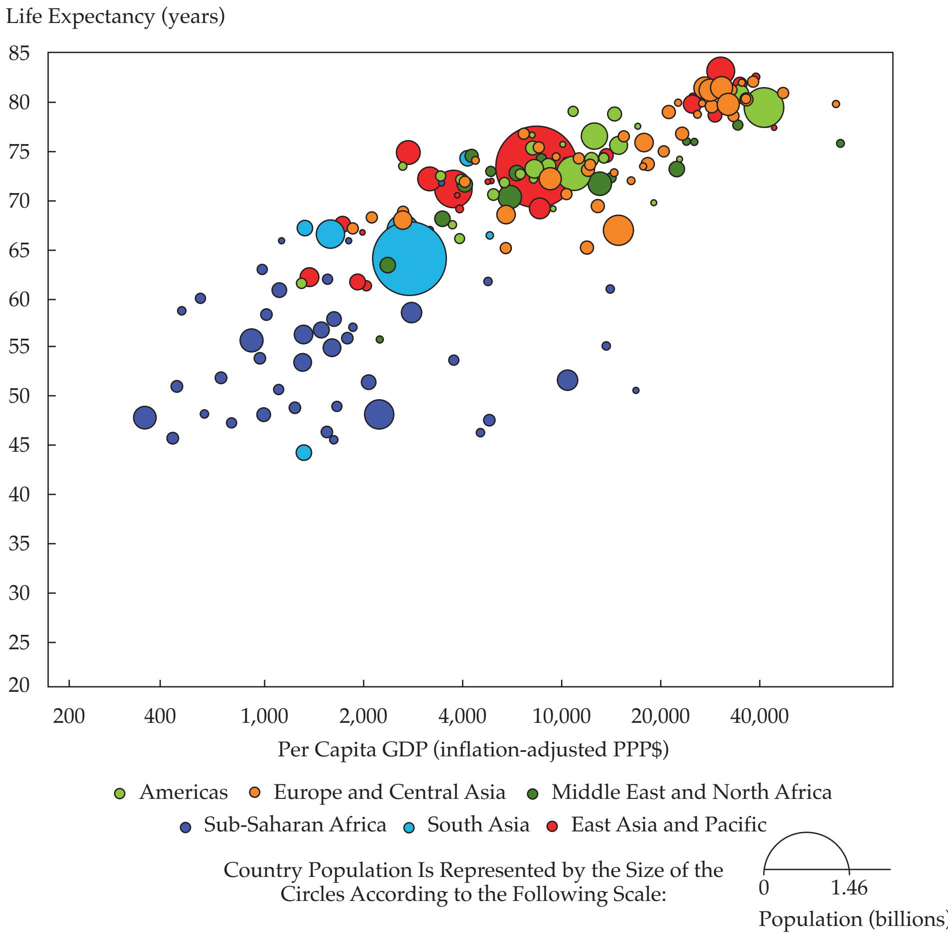
tremendous global economic growth over the past decade by gathering and channeling vast amounts of capital from asset owners in one part of the world to entrepreneurs in other parts of the world who are able to make better use of it. But globally connected capital markets imply that local financial shocks will spread more quickly to other regions, as we have seen with the recent financial crisis and the spillover effects of the ongoing European sovereign debt crisis.

This new world order is the context in which the adaptive markets hypothesis (AMH) has emerged as a more complete explanation of the behavior of financial markets and their participants.[4] The AMH begins with the recognition that human behavior is a complex combination of multiple decision-making systems, of which logical reasoning is only one among several. The ability to engage in abstract thought, to communicate these thoughts to others, and to act in a coordinated fashion to achieve complex goals seem to be uniquely human traits that have allowed us to dominate our environment like no other species, ushering in the age of *Homo economicus* (at least according to economists). Neuroscientists have traced these abilities to a region of the brain known as the *neocortex*, an anatomical structure that is unique to mammals and is particularly large and densely connected in *Homo sapiens*.[5] On an evolutionary timescale, the neocortex is the most recent component of the brain—hence, its name.

Before humans developed these impressive faculties for abstraction, however, we still managed to survive in a hostile and competitive world, thanks to more primitive decision-making mechanisms. One example is the fight-or-flight response, a series of near-instantaneous physiological reactions to physical threats that include increased blood pressure and blood flow to the large-muscle groups; the constriction of blood vessels in other

Figure 4. Population Size, Per Capita GDP, and Average Life Expectancy for Various Countries, 1939 and 2009 (continued)

B. 2009



Note: PPP stands for purchasing power parity.

Source: http://gapminder.org.

parts of the body; rapid release into the bloodstream of such nutrients as glucose; decreased appetite, digestive activity, and sexual desire; tunnel vision and loss of hearing; and much faster reflexes.[6] In short, the fight-or-flight response prepares us to defend ourselves from attack by either evading our attacker or fighting to the death. This complex collection of decisions is not made voluntarily and after careful deliberation but is a "hardwired" automatic response in most animal species; if we had to think about whether to react in this manner, we would end up as dinner for less pensive predators.

The key insight regarding these various decision-making mechanisms is that they are not completely independent. In some cases, such as the fight-or-flight response, they work together to achieve a single purpose: a physiological reaction involving several systems that are typically independent but that become highly correlated under specific circumstances.[7] Such coordination, however, sometimes implies that certain decision-making components take priority over others. For example, Baumeister, Heatherton, and Tice (1994) documented many instances in which an extreme emotional reaction can "short-circuit" logical deliberation, inhibiting activity in the neocortex. From an evolutionary standpoint, this makes perfect sense—emotional reactions are a call to arms that should be heeded immediately because survival may depend on it, and higher-brain functions, such as language and logical reasoning, are suppressed until the threat is over (i.e., until the emotional reaction subsides). When being chased by a tiger, it is more advantageous to be frightened into scrambling up a tree than to be able to solve differential equations!

From a financial decision-making perspective, however, this reaction can be highly counterproductive. Adaptations like the fight-or-flight response emerged in response to physical threats, not financial losses, yet our instinctive response to both is much the same. The behavioral biases that psychologists and behavioral economists have documented are simply adaptations that have been taken out of their evolutionary context: Fight-or-flight is an extremely effective decision-making system in a street fight but is potentially disastrous in a financial crisis.[8]

The focus of the AMH is not on any single behavior but, rather, on how behavior *responds* to changing market conditions. In the framework of the AMH, individuals are neither perfectly rational nor completely irrational but are intelligent, forward-looking, competitive investors who adapt to new economic realities. When John Maynard Keynes was criticized for flip-flopping on the gold standard, he is said to have replied, "When the facts change, sir, I change my mind; what do you do?" By modeling the *change* in behavior as a function of the environment in which investors find themselves, it becomes clear that efficient and irrational markets are two extremes, neither of which fully captures the state of the market at any point in time.

In fact, human responses to risk are more subtle than the fight-or-flight mechanism might imply. One striking illustration is the "Peltzman effect," named after the University of Chicago economist Sam Peltzman. In a controversial empirical study on the impact of government regulations requiring the use of automobile safety devices, such as seat belts, Peltzman (1975) found that these regulations did little to reduce the number of highway deaths because people adjusted their behavior accordingly, presumably driving faster and more recklessly. Although in certain cases, the number of fatalities among the occupants of autos involved in accidents did decline over time, his analysis showed that this decline was almost entirely offset by an *increase* in the number of pedestrian deaths and nonfatal accidents. He concluded that the benefits of safety regulations were mostly negated by changes in driver behavior. Since then, many studies have extended Peltzman's original study by considering additional safety devices, such as air bags, antilock brakes, and crumple zones. In some cases, these new studies have confirmed, but in other cases they have refuted, Peltzman's original findings after controlling for such other factors as enforcement practices, driver age, rural versus urban roads, vehicle weight, and so on.[9]

These mixed results are not surprising given the many different contexts in which we drive automobiles. While an impatient commuter might well take advantage of improved safety by driving faster and getting to work a few minutes early, the same may not apply to visiting tourists. In a recent study of the Peltzman effect, however, Sobel and Nesbit (2007) investigated the one driving context in which there are very few confounding factors and no doubt that all drivers are singularly focused on arriving at their final destination as quickly as possible—NASCAR races. Their conclusion: "Our results clearly support the existence of offsetting behavior in NASCAR—drivers do drive more recklessly in response to the increased safety of their automobiles" (p. 81). When the only goal is to reduce driving time, it seems perfectly rational that increased safety would induce drivers to drive faster. From a financial perspective, this is completely consistent with basic portfolio theory: If an asset's volatility declines but its expected return remains unchanged, investors will put more money into such an asset, other things (like correlations to other assets) being equal.

If safety improvements are genuinely effective, such adaptive behavior may result in the appropriate outcomes. But what if these "improvements" were not, in fact, as effective as they were *perceived* to be? In such cases, drivers may end up taking more risk than they intended to because they feel safer than they really are, greatly increasing the likelihood of unintended consequences. Risk perception may differ from risk reality, which played a critical factor in the recent financial crisis. Given the AAA ratings of the safest tranches of collateralized debt obligations (CDOs) and the relatively short and default-free history of those new securities, investors may have thought they were safer than they were.[10]

It is easy to see how the adaptive nature of human risk preferences can generate market bubbles and crashes if perception can become disconnected from reality from time to time. This potential disconnect is one of the most important motivations for producing and publicizing accurate, objective, and timely risk analytics in financial contexts—negative feedback loops are one of nature's most reliable mechanisms for maintaining stability, or *homeostasis*. The aggregation of these individual behavioral dynamics explains why markets are never completely efficient or irrational—they are simply adaptive.

Practical Implications

Although in its infancy, the AMH offers at least five immediate practical implications for investors, portfolio managers, and policymakers. Perhaps the most important implication from an investment management perspective is that the trade-off between risk and reward is not stable over time or circumstances but varies as a function of the population of market participants and the business environment in which they are immersed. During periods of market dislocation—when fear rules the day—investors will reduce their holdings of risky assets and move into safer investments. This will have the effect of reducing the average return on risky assets and increasing the average return on safer ones, exactly the opposite of what rational finance predicts: The "madness of mobs" replaces the wisdom of crowds. However, during more "normal" periods when market conditions are benign (i.e., when price fluctuations are within historically observed ranges and current events have no overriding consequences for market valuations or the conduct of business), assumptions A1–A6 are good approximations to reality and the wisdom of crowds returns.

If, over an extended period of time, the wisdom of crowds is more common than the madness of mobs—as theory and empirical evidence seem to suggest—then statistical averages over long horizons (e.g., market risk premiums) will largely reflect the wisdom of crowds. This observation, however, does not imply that the wisdom of crowds must hold at *every* point in time. There may be periods of collective fear or greed when the madness of mobs takes over, not unlike the notion of "punctuated equilibria" in evolutionary biology when, after long periods of evolutionary stasis, relatively sudden changes lead to extinctions and new species in their aftermath.[11] It is precisely during such periods in financial history that bubbles and crashes emerge, and assumptions A1–A6 become less accurate approximations to reality.

This dynamic can be observed in the historical data, as **Table 1** and **Figure 5** illustrate. Table 1 reports the historical means and standard deviations of stocks and bonds from January 1926 to December 2010, which confirms the traditional view that there is a positive risk–reward trade-off. However, Figure 5, which depicts 1,250-day (approximately five-year) rolling-window geometrically compounded returns and standard deviations of daily CRSP value-weighted index returns, shows a time-varying and often negative relationship between the two; the correlation between these two daily series is –59.9 percent!

This empirical anomaly was first documented by Fischer Black (1976), who explained it as a "leverage effect": When equity prices decline (generating negative returns), this implies higher equity volatility because corporations with debt in their capital structure are now more highly leveraged. This explanation seems eminently plausible, except that this so-called leverage effect is still present and even *stronger* among all-equity-financed companies (Hasanhodzic and Lo 2011). The AMH provides an alternative explanation: Sudden increases in equity volatility cause a significant portion of investors to reduce their equity holdings rapidly through a fight-or-flight response, better known in financial contexts as a "flight to safety." This process of divestment puts downward pressure on equity prices and upward pressure on the prices of safer assets, causing the normally positive association between risk and reward to be temporarily violated. Once these emotional responses subside, the madness of mobs is replaced by the wisdom of crowds and the usual risk–reward relation is restored.

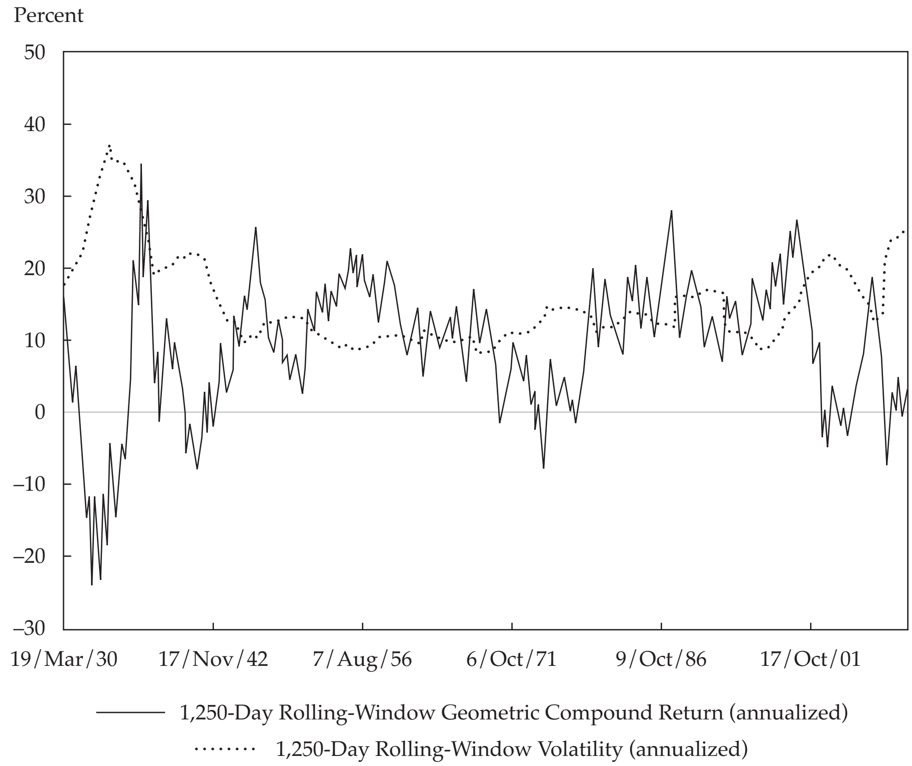
The second implication of the AMH is that market efficiency is not an all-or-nothing condition but a continuum, one that depends on the relative proportion of market participants who are making investment decisions with their prefrontal cortexes versus their more instinctive faculties, such as fight-or-flight. In other words, the *degree* of market efficiency—similar to the energy efficiency of an air conditioner or a hot-water heater—should be measured; it is directly related to the degree to which a given set of market participants is adapted to the environment in which the market has developed. A relatively new market is likely to be less efficient

Table 1. Historical Means and Standard Deviations of Stocks and Bonds, January 1926–December 2010

Asset Class	Geometric Mean (%)	Arithmetic Mean (%)	Standard Deviation (%)
Small-company stocks	12.1	16.7	32.6
Large-company stocks	9.9	11.9	20.4
Long-term corporate bonds	5.9	6.2	8.3
Long-term government bonds	5.5	5.9	9.5
Intermediate-term government bonds	5.4	5.5	5.7
U.S. Treasury bills	3.6	3.7	3.1

Source: Ibbotson (2011, Table 2–1).

Figure 5. Geometrically Compounded Returns and Standard Deviations of Daily CRSP Value-Weighted Index Returns over 1,250-Day Rolling Windows, 19 March 1930 to 31 December 2010



Sources: CRSP and author's calculations.

than a market that has been in existence for decades, but even in the latter case, inefficiencies can arise if the environment shifts or the population of investors changes materially. In fact, market efficiency can be measured and managed, as many security exchanges routinely do as part of their ongoing efforts to improve market quality. This perspective implies that assumptions A1–A6 should be viewed not as either true or false but, rather, as approximations that may become more or less accurate as market conditions and investor populations change.

This observation leads to a third implication of the AMH, which is that investment policies must be formulated with these changes in mind and should adapt accordingly. When assumptions A1–A6 are reasonable approximations to current conditions, traditional investment approaches are adequate, but when those assumptions break down, perhaps because of periods of extreme fear or greed, the traditional approaches may no longer be effective. One obvious example is the notion of diversification. Diversifying one's investments across 500 individual securities—for instance, the stocks in the S&P 500 Index—used to be sufficient to produce relatively stable and attractive returns over extended periods of time. However, in today's environment, these 500 securities are so tightly coupled in their behavior that they offer much lower diversification benefits than in the past. The principle of diversification is not wrong; it is simply harder to achieve in today's macro-factor-driven markets. Therefore, its implementation must be adapted to the current environment (e.g., diversifying across a broader array of investments in multiple countries and according to factor exposures instead of or in addition to asset classes).

A fourth implication of the AMH involves an important consequence of competition, innovation, and natural selection in financial markets: the transformation of alpha. Under assumptions A1–A6, alpha should always equal zero. Under the AMH, alpha can be positive from time to time, but any unique and profitable investment opportunity will eventually be adopted by many investors, in which case the alpha will either be reduced to zero or reach an equilibrium level at which the risks associated with its exploitation are sufficient to limit the number of willing participants to some finite and sustainable number. This is one possible explanation of the relatively stable risk–reward trade-off of U.S. equities during the Great Modulation, and of why that trade-off seems to have changed in recent years as greater consolidation among asset owners, owing to economies of scale and scope, and mounting pressure in low-yield environments to find new sources of expected return have intensified global competition across all financial markets and strategies. Even more striking examples can be found in the hedge fund industry (see Lo 2010; Getmansky, Lee, and Lo, forthcoming 2012), the Galápagos Islands of the financial sector, where evolution is apparent to the naked eye and alphas decay rapidly, only to reappear a few years later after enough investors and managers have moved on to greener pastures.

Finally, the AMH has a significantly different implication for asset allocation than does the traditional investment paradigm. Under the stable environment of assumptions A1–A6, simple asset allocation rules, such as a static 60/40 stock/bond portfolio, might suffice. But if there is significant volatility of volatility and risk premiums also vary over time, then defining portfolios in terms of the usual asset-based portfolio weights may not be very useful from a decision-making perspective. In particular, a 60 percent asset weight in equities may yield a volatility of $0.60 \times 0.20 = 12$ percent during normal times, but during the fourth quarter of 2008, when the CBOE Volatility Index reached 80 percent, such an allocation would have yielded a volatility of approximately 48 percent. Given that investors are usually more concerned with risk and reward than with the numerical values of their portfolio weights, the AMH suggests that denominating asset allocations in risk units may be more useful and more stable, particularly when assumptions A1–A6 break down. For example, if an investor is comfortable with an annualized return volatility of 10 percent for her entire portfolio, this can be the starting point of an asset allocation strategy in which a risk budget of 10 percent is allocated across several asset classes—say, 5 percent risk to equities, 3 percent risk to bonds, and 1 percent risk to commodities.[12] As the volatilities and correlations of the underlying assets change over time, the portfolio weights change in tandem to maintain constant risk weights and portfolio volatility, reducing the potential for fight-or-flight responses because the investor experiences fewer surprises with respect to her portfolio's realized risk levels.[13]

Specifying risk allocations has the added benefit that during periods of heightened volatility, exposures to risky assets will be reduced so as to maintain comparable levels of volatility; recall that these periods are precisely when the madness of mobs is most likely to emerge, causing the expected returns of risky assets to decline owing to flight-to-safety divesting. In the traditional investment paradigm, it never pays to engage in such "tactical" shifts because market timing has been shown to be virtually impossible and, therefore, ineffective, and by reducing exposure to risky assets from time to time, a portfolio will forgo the risk premiums associated with those risky assets. This misleading conclusion provides the starkest contrast between the EMH and the AMH—if risk premiums and volatilities are constant over time, then static portfolio weights may indeed be adequate, but if they vary over time in response to observable market conditions, then an adaptive strategy may be superior.

Risk-denominated portfolio weights are only part of the solution to the asset allocation problem under the AMH; the impact of time-varying expected returns and correlations of individual asset classes, which may be quite different under various market regimes, must also be taken into account. A more integrated approach is to use adaptive statistical estimators for all the relevant parameters of an investor's environment and construct allocations that incorporate estimation error, regime shifts, institutional changes, and more realistic models of investor preferences and behavior. Such an approach has the added advantage that in stable environments, truly adaptive portfolio policies will eventually reduce to traditional static ones, implying little cost in implementing adaptive strategies during normal periods and significant benefits during market dislocations.

The practical implementation of the AMH is clearly more challenging than the simpler heuristics of the traditional investment paradigm. These challenges, however, are considerably less daunting today given the vast improvements in trading technology, automated execution algorithms, lower trading costs, better statistical measures of time-varying parameters using various online data sources, the greater liquidity of exchange-traded index futures and other derivative securities, and better-educated investors and portfolio managers. Nevertheless, the increased complexity of today's investment environment is undeniable. It is a reflection not just of recent financial crises but of a much larger and more complex global economy to which we must learn to adapt by applying more effective financial technologies.

Conclusion

There is a well-known parable about five monks who, blind from birth, encounter an elephant for the very first time and are later asked to describe it. The monk who felt the elephant's trunk insists that an elephant is just like a snake, the monk who felt the elephant's leg claims that an elephant is just like a tree, and so on. Their individual perspectives are not wrong, but they each possess an incomplete understanding of the animal. Under stable, stationary, and predictable economic conditions, markets generally work well and the EMH serves as a reasonably good approximation to reality; under more dynamic and stochastic environments, the EMH becomes less plausible and behavioral regularities seem to emerge. The AMH provides an integrated and logically consistent framework for reconciling these disparate perspectives and offers several practical insights with respect to investing in the current economic climate of uncertainty and market turmoil.

Of course, the AMH is not yet as well developed as the EMH, but this is changing as we begin to collect more relevant data for measuring the evolutionary dynamics of financial markets and investor behavior across time and circumstances. The early evidence suggests that the AMH can explain not only departures from the EMH and behavioral regularities but also how markets shift from the wisdom of crowds to the madness of mobs and back again.[14] By studying the forces behind such changes, we can begin to develop more effective models for managing our investments and come closer to the ultimate goal of efficiently allocating scarce resources to support steady economic growth while maintaining financial stability.

I thank Tom Brennan, Jerry Chafkin, Jayna Cummings, Arnout Eikeboom, and Bob Merton for helpful comments and discussion. The views and opinions expressed in this article are those of the author only and do not necessarily represent the views and opinions of AlphaSimplex Group, MIT, any of their affiliates and employees, or any of the individuals acknowledged above.

This article qualifies for 0.5 CE credit.

Notes

1. For the hazards of "physics envy" in finance, see Lo and Mueller (2010).
2. This term also refers to both economic and regulatory reforms that were put in place in the wake of the Great Depression to modulate financial activity, including much of the U.S. code that now governs the entire financial system: the Glass–Steagall Act of 1932, the Banking Act of 1933, the Securities Act of 1933, the Securities Exchange Act of 1934, the Investment Company Act of 1940, and the Investment Advisers Act of 1940. The Great Modulation should not be confused with the Great Moderation, a term coined by Stock and Watson (2002) that refers to the 1987–2007 period of lower volatility in the U.S. business cycle. The two concepts are clearly related.
3. I obtained world population data from the U.S. Census Bureau's International Data Base. The U.S. Census Bureau reports several sources for world population estimates from 10,000 BC to 1950, some of which include lower and upper estimates; I averaged these estimates to yield a single estimate for each year in which figures are available. From 1951 to 2011, the U.S. Census Bureau provides a unique estimate per year. For further details, see www.census.gov/population/international/data/idb/worldpopinfo.php.
4. See Lo (2004, 2005) and Brennan and Lo (2011) for more detailed expositions of the adaptive markets hypothesis.
5. See Schoenemann (2006) for a review of the literature on human brain evolution and a comparison of subcomponents of the brain across hominid species.
6. See de Becker (1997), Zajonc (1980, 1984), and Lo (2011).
7. It is no coincidence that the all-too-familiar pattern of abruptly increasing correlations of previously uncorrelated activities exists in physiological phenomena as well as in financial time series—fight-or-flight responses can trigger flights to safety.
8. See Lo (2011) for a more detailed discussion of the neuroscientific perspective on financial crises and Brennan and Lo (2011) for an evolutionary framework in which various behavioral regularities, such as risk aversion, loss aversion, and probability matching, emerge quite naturally through the forces of natural selection.
9. See, for example, Crandall and Graham (1984); Farmer, Lund, Trempel, and Braver (1997); and Cohen and Einav (2003).
10. However, even in this case, the wisdom of crowds suggested an important difference between CDOs and other securities with identical credit ratings. For example, in an April 2006 publication by the *Financial Times* (Senior 2006), Cian O'Carroll, European head of structured products at Fortis Investments, explained why CDOs were in such high demand: "You buy a AA-rated corporate bond, you get paid LIBOR plus 20 bps; you buy a AA-rated CDO, and you get LIBOR plus 110 bps." Did investors wonder why CDOs were offering 90 bps of additional yield or where that extra yield might be coming from? It may not have been the disciples of the EMH who were misled during those frothy times, but more likely those who were convinced they had discovered a free lunch.
11. See, for example, Eldredge and Gould (1972). This reference to punctuated equilibria is not merely an analogy—it is meant to apply quite literally to financial institutions and economic relationships, which are subject to evolutionary forces in their own right.
12. The fact that the volatilities of the individual components do not add up to 10 percent is not a typographical error; it is a deliberate reminder that the return volatility of a portfolio is not the sum of the volatilities of the individual components (owing to correlations among the assets as well as the nonlinearity of the square-root function). Moreover, cash is also an investable asset, but because its nominal returns have zero volatility, cash investments will not

appear in any risk budget despite their importance for managing portfolio volatility. Therefore, the notion of a "risk budget" must be used with caution so as not to mislead or confuse investors.

13. This asset allocation strategy may seem like "portfolio insurance" and related dynamic asset allocation strategies (Black and Perold 1992; Perold and Sharpe 1995), but there are several important differences. The motivation for risk-denominated asset allocation (RDAA) strategies is the nonstationarity of risk levels due to behavioral responses; portfolio insurance typically assumes stationary returns. Changes in portfolio weights from RDAA strategies are driven by changes in short-term volatility; changes in portfolio weights from portfolio insurance strategies are driven by short-term losses. And finally, the amount of time variation in the portfolio weights of RDAA strategies is determined by the volatility of volatility—if volatility is relatively stable, then RDAA strategy weights will be relatively smooth. The time variation in portfolio insurance strategy weights is determined by the level of volatility—higher volatility will require more frequent portfolio rebalancing. Of course, the two types of strategies will likely yield positively correlated return streams because losses are usually accompanied by increased volatility (Black 1976; Hasanhodzic and Lo 2011); hence, RDAA and portfolio insurance strategies may be changing risk levels at approximately the same times. However, the magnitude and frequency of those changes are not the same and are driven by different variables, so the correlation will not be perfect and the ultimate risk–reward profiles of the two types of strategies can be quite different.

14. See, for example, Brennan and Lo (2011, 2012); Getmansky, Lee, and Lo (forthcoming 2012); and Lo (2010, 2011).

References

Baumeister, R., T. Heatherton, and D. Tice. 1994. *Losing Control: How and Why People Fail at Self-Regulation*. San Diego: Academic Press.

Black, F. 1976. "Studies of Stock Price Volatility Changes." Proceedings of the 1976 Meeting of the American Statistical Association (Business and Economics Section):177–181.

Black, F., and A. Perold. 1992. "Theory of Constant Proportion Portfolio Insurance." *Journal of Economic Dynamics & Control*, vol. 16, no. 3–4 (July–October):403–426.

Brennan, T., and A. Lo. 2011. "The Origin of Behavior." *Quarterly Journal of Finance*, vol. 1, no. 1 (March):55–108.

———. 2012. "An Evolutionary Model of Bounded Rationality and Intelligence." MIT Laboratory for Financial Engineering Working Paper No. 2012–001.

Cohen, A., and L. Einav. 2003. "The Effect of Mandatory Seat Belt Laws on Driving Behavior and Traffic Fatalities." *Review of Economics and Statistics*, vol. 85, no. 4 (November):828–843.

Crandall, R., and J. Graham. 1984. "Automobile Safety Regulation and Offsetting Behavior: Some New Empirical Estimates." *American Economic Review*, vol. 74, no. 2 (May):328–331.

de Becker, G. 1997. *The Gift of Fear: Survival Signals That Protect Us from Violence*. Boston: Little, Brown and Company.

Eldredge, N., and S. Gould. 1972. "Punctuated Equilibria: An Alternative to Phyletic Gradualism." In *Models in Paleobiology*. Edited by T. Schopf. San Francisco: Freeman, Cooper:82–115.

Farmer, C., A. Lund, R. Trempel, and E. Braver. 1997. "Fatal Crashes of Passenger Vehicles before and after Adding Antilock Braking Systems." *Accident Analysis and Prevention*, vol. 29, no. 6 (November):745–757.

Getmansky, M., P. Lee, and A. Lo. Forthcoming 2012. "Hedge Funds: An Industry in Transition." *Annual Review of Financial Economics*.

Hasanhodzic, J., and A. Lo. 2011. "Black's Leverage Effect Is Not Due to Leverage." Working paper (15 February).

Ibbotson, R. 2011. *Ibbotson® SBBI® 2011 Classic Yearbook*. Chicago: Morningstar, Inc.

Lo, A. 2004. "The Adaptive Markets Hypothesis: Market Efficiency from an Evolutionary Perspective." *Journal of Portfolio Management*, vol. 30, no. 5 (30th Anniversary Issue):15–29.

———. 2005. "Reconciling Efficient Markets with Behavioral Finance: The Adaptive Markets Hypothesis." *Journal of Investment Consulting*, vol. 7, no. 2 (Winter/Spring):21–44.

———. 2010. *Hedge Funds: An Analytic Perspective*. Princeton, NJ: Princeton University Press.

———. 2011. "Fear and Greed and Financial Crises: A Cognitive Neurosciences Perspective." Forthcoming in *Handbook on Systemic Risk*. Edited by J.P. Fouque and J. Langsam. Cambridge, U.K.: Cambridge University Press.

Lo, A., and M. Mueller. 2010. "WARNING: Physics Envy May Be Hazardous to Your Wealth." *Journal of Investment Management*, vol. 8, no. 2 (Second Quarter):13–63.

Peltzman, S. 1975. "The Effects of Automobile Safety Regulation." *Journal of Political Economy*, vol. 83, no. 4 (August):677–726.

Perold, A., and W. Sharpe. 1995. "Dynamic Strategies for Asset Allocation." *Financial Analysts Journal*, vol. 51, no. 1 (January/February):149–160.

Schoenemann, T. 2006. "Evolution of the Size and Functional Areas of the Human Brain." *Annual Review of Anthropology*, vol. 35 (October):379–406.

Senior, C. 2006. "CDOs Explode after Growing Interest." *FT Mandate* (April).

Sobel, R., and T. Nesbit. 2007. "Automobile Safety Regulation and the Incentive to Drive Recklessly: Evidence from NASCAR." *Southern Economic Journal*, vol. 74, no. 1 (July):71–84.

Stock, J., and M. Watson. 2002. "Has the Business Cycle Changed and Why?" In *NBER Macroeconomics Annual*. Cambridge, MA: National Bureau of Economic Research.

Zajonc, R. 1980. "Feeling and Thinking: Preferences Need No Inferences." *American Psychologist*, vol. 35, no. 2 (February):151–175.

———. 1984. "On the Primacy of Affect." *American Psychologist*, vol. 39, no. 2 (February):117–123.