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Capital Ideas Revisited

The Prime Directive, Sharks, and The Wisdom of Crowds

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- **Market efficiency is an important topic for active money managers because it is the starting point for a thoughtful investment process.**
- **The theoretical foundation for market efficiency rests on three arguments: rational agents, random investor errors, and a no-arbitrage assumption. We argue that the second approach, which falls under the rubric on complex adaptive systems, is the most useful.**
- **We show how standard finance and experimental economics fit into the complex systems framework.**
- **Behavioral finance is valuable for studying collectives. Since reductionism fails in markets, studying individual errors is not fruitful.**
- **Statistical studies of the market reveal features that are at odds with standard theory, but consistent with a complex systems approach.**

Summary

A quality investment process begins with a thoughtful view of market efficiency. Substantial evidence suggests that active institutional managers in the aggregate add little or no value versus passive index funds. Without some sense of how and why markets are efficient or inefficient, investors have no sound reason to believe they can systematically deliver superior returns.

We offer a framework to understand market efficiency based on the theory of complex adaptive systems. The framework also offers insight into market inefficiency and how a long-term investor should try to take advantage of inefficiency. Along the way, we show how developments in standard finance theory, behavioral finance, experimental economics, and prediction markets fit into the complex adaptive system framework.

Here are the key points:

- We evaluate standard finance's three approaches to explaining market efficiency: rational agents, independent errors, and no-arbitrage. We argue that the rational agent and no-arbitrage arguments rest on questionable assumptions and offer predictions that don't square with the empirical facts.

- A complex adaptive systems approach to markets is based on the large-scale behaviors that emerge from the interaction of a heterogeneous group of investors. We suggest the conditions under which markets are efficient and inefficient, and note the stylized predictions of the complex systems approach.

- The booming behavioral finance movement has much to offer. Investors, however, must be careful to avoid the reductionist trap and study psychology on a collective, not individual, basis. Suboptimal decisions by individuals do not suggest an inefficient market unless the errors are non-independent.

- Experimental economics shows that markets can attain competitive equilibrium with surprisingly weak assumptions about agent knowledge, and that bubbles and crashes occur under certain circumstances.

- The statistical properties of markets—*what* market results look like—are consistent with a complex systems approach but appear contrary to much that the standard theory predicts. Evidence suggests some statistical features, like large-scale changes, are endogenous to many complex systems. This discussion bears directly on discussions about risk measurement techniques.

Introduction

Market efficiency is a very important topic for active investment managers. Without a clear understanding of how and why markets are efficient or inefficient, investors have no foundation for establishing an investment strategy. To win a game, you must understand the rules.

Still, very few active investors think carefully about market efficiency. Most investors take market inefficiency for granted—their professional "reason to be" depends on it—but have very little to substantiate their perception. Some sense of how and why markets are, or can become, inefficient provides insight on ways to generate better-than-expected risk-adjusted results.

Practioners must logically believe that markets exist between the extremes of pure efficiency and inefficiency. Markets that are *always* inefficient are a mug's game, because an investor has no assurance that the difference between price and value will vanish. Conversely, perfectly efficient markets afford no opportunity for excess returns.

The debate over market efficiency tends to break into two broad camps. The first camp, which includes most financial economists and passive money managers, argues for market efficiency—security prices fully reflect all available information.[1] The most lethal arrow in the market efficiency quiver is the overwhelming evidence that most active managers underperform passive indexes over time. [2]

A sizable majority of active managers and a smaller percentage of academics—especially those involved with behavioral finance—comprise the second camp. This group suggests that prices periodically deviate substantially from warranted value. Believers marshal evidence from a host of anomalies, including booms, crashes, and a handful of investors who have consistently beat the market over time.

In his famous book *The Structure of Scientific Revolutions*, Thomas Kuhn wrote, "Anomaly appears only against the background provided by the paradigm." [3] The construction of modern finance theory, which Peter Bernstein's *Capital Ideas* documents beautifully, plays a crucial role in how we frame the market efficiency debate today. Since the terms of today's debate are an artifact of the theory's intellectual path, we will look critically at how neoclassical finance developed along with its explicit and implicit assumptions. In the end, we will argue that the standard theory is in its twilight. We already have richer ways to think about markets that are descriptively more robust and truer to empirical results.

This is not to say that we should not celebrate the contributions of our finance fathers, including Louis Bachelier, Harry Markowitz, Paul Samuelson, William Sharpe, James Tobin, Merton Miller, Franco Modigliani, Eugene Fama, Fischer Black, Myron Scholes, and Robert Merton (this group has amassed eight Nobel prizes). They created theory to explain important phenomena in financial economics, and their theories immediately became touchstones. Without a solid theoretical foundation as a basis to compare results, a scientific field will not advance.

In the first part of this essay, we look at standard finance's approaches to explaining market efficiency. As we will see, two of the three main approaches to explain efficiency rest on dubious assumptions, and more significantly, make predictions the empirical results do not substantiate.

Next, we look at a complex adaptive systems approach to markets. Complex systems consider the large-scale behaviors that emerge from the interaction of a heterogeneous group of agents. A complex systems approach describes a market mechanism—*how* we get to market results. From social insects, to experimental economics, to decision markets, to stock markets, we will look at a host of collective phenomena and see under what conditions they generate good and poor results. Here, too, we consider the role of behavioral finance and provide high-level predictions of complex systems theory.

Finally, we look at the statistical properties of markets—*what* market results look like. Certain statistical features, like large-scale changes, are endogenous to many complex systems, a topic that also bears directly on a discussion of risk.

In a future piece, we will turn to a more practical question: if a complex adaptive system approach *is* the right way to understand markets, how can active investors beat the market?

The Prime Directive and Sharks

I believe there is no other proposition in economics which has more solid empirical evidence supporting it than the Efficient Market Hypothesis.

Michael C. Jensen
Some Anomalous Evidence Regarding Market Efficiency [4]

In his excellent book, *Inefficient Markets*, Andrei Shleifer describes the three arguments that comprise the theoretical foundation for market efficiency. The assumptions underlying these arguments become less restrictive as you go down the list: [5]

1. *Investor rationality*. The models here assume that investors are rational, which means they correctly update their beliefs when new information is available and make normatively acceptable choices given expected utility theory.[6]
2. *The random errors of investors cancel out*. This model does allow investors to make errors, but assumes these errors are independent. The errors cancel out, leaving an efficient result. (Pierre-Simon LaPlace and Simeon-Denis Poisson used this idea to describe how a distribution of errors around celestial observations distilled to an accurate number. [7])
3. *Arbitrage*. Even if all investors are not rational, a small set of rational investors use arbitrage to remove pricing errors. So the average investor doesn't matter; the marginal investor sets prices.

In the short time between 1952 and 1973, a handful of researchers devised the theories that form finance's bedrock. These theories rely largely on the rational agent and arbitrage argument. A very brief synopsis follows:

Mean/variance efficiency. According to mean-variance efficiency, investors rationally trade-off risk and return in a linear fashion. Markowitz (1952) first showed how to optimize the risk/reward tradeoff in a portfolio. Sharpe (1964), John Lintner (1965), and Jan Mossin (1966) extended the concept into the capital asset pricing model (CAPM), which extended Markowitz while offering much more computational simplicity.[8]

Arbitrage. Modigliani and Miller (1958) used an arbitrage argument to show that, under certain conditions, a firm's value is independent of its capital structure. Milton Friedman (1953) made the arbitrage case in the context of markets, arguing that rational investors would rapidly reverse the dislocations created by irrational investors. Arbitrage is also a central component of Fama's (1965) case that stock price changes are independent, pertinent for the efficient market hypothesis.

Later, Black and Scholes (1973) developed their eponymous options pricing model on the idea of arbitrage. Option models generally rely on a replicating portfolio, a mix of securities that replicates the option's payoff. A no-arbitrage condition is a critical assumption in the model.

These two approaches are fundamentally different. The rational model relies on notions of general equilibrium and is an *absolute* pricing model. In contrast, the arbitrage approach is a *relative* pricing model and doesn't ask where the prices came from. About arbitrage, physicist-cum-quant Emanuel Derman quipped, "If you want to know the value of a security, use the value of a similar security, and compare. Everything else is commentary." In reality, many models blend the two approaches to best solve a given problem. [9]

We can easily see how combining rational agents and arbitrage makes for a powerful one-two punch. If we assume rational agents, we get the right price. But even with non-rational agents, (in violation of mean/variance efficiency), enough arbitrageurs are around to make the market look *as if* it's rational.

Didier Sornette, in his sweeping and provocative book *Why Stock Markets Crash*, notes, "the no-arbitrage condition together with rational expectations is not a mechanism. It does not explain its own origin." [10] This distinction is vital, because even if these arguments help to describe the *outcome* of the market mechanism, they do not describe the mechanism itself.

Let's look more critically at these two arguments.

Perhaps no single concept is more central in neoclassical economics and finance than the assumption of agent rationality. Financial economist Mark Rubinstein explains: [11]

> When I went to financial economist training school, I was taught ***The Prime Directive*** . . . Whatever else I would do, I should follow ***The Prime Directive***: *Explain asset prices by rational models. Only if all attempts fail, resort to irrational investor behavior*. (Emphasis original.)

Where did the idea of rational agents come from? We can trace today's finance theory back to 19th century physics. In the preface to *Handbook of The Economics of Finance*, editors George Constantinides, Milton Harris, and Rene Stulz explain, "the modern quantitative approach to finance has its origins in neoclassical economics." [12] Economist and science historian Philip Mirowski continues the link, "neoclassical [economic] theory was directly copied from mid-nineteenth-century energy physics." [13]

Specifically, late-19th-century economists equated preferences (or utility) with potential energy, allowing them to adopt the physics models. Mirowski suggests the economists imitated physics based on their motivation to make economics "intrinsically scientific", and the models they adopted embraced the prevailing deterministic views of that day.

The problem, he argues, is that utility and energy are fundamentally different principles. Conservation principles in physics have no straightforward analog in economics. Mirowski suggests, "This suppressed conservation principle, forgetting the conservation of energy while simultaneously appealing to the metaphor of energy, is the Achilles heel of all neoclassical economic theory, the point at which the physical analogy breaks down irreparably."

Mirowski's in-depth study of the link between physics and economics reflects poorly on the economists. Yet the physics-inspired models remain the bread and butter of many economists. He continues, "Economists have consistently lagged behind physicists in developing and elaborating metaphors; they have freeloaded off of physicists for their inspiration, and appropriated it in a shoddy and slipshod manner." [14]

The extremity of the rational agent assumption has not been lost on financial economists. But as Friedman argues, the real test of a theory is not the realism of its assumptions but the quality of its predictions. By this standard, the rational agent model is wounded.

One of classic finance's predictions is very limited trading activity. As a practical matter, this prediction lands wildly off the mark. In a recent survey of asset pricing, financial economist John Cochrane states the point directly: [15]

> The classic theory of finance has no volume at all: Prices adjust until investors are happy to continue doing what they were doing all along, holding the market portfolio. Simple modifications such as lifecycle and rebalancing motives don't come near to explaining observed volume. Put bluntly, the classic theory of finance predicts that the NYSE and NASDAQ do not exist.

Further, empirical tests of mean/variance efficiency have questioned its predictive value. Fama and French (1992), for example, flatly assert, "tests do not support the most basic prediction of the SLB [Sharpe-Linter-Black] model, that average returns are positively related to the market's." In a follow up paper (2004), they add, "the empirical record of the [SLB] model is poor—poor enough to invalidate the way it is used in applications."

Even outright rejection of the rational agent model doesn't suggest inefficient markets if the no-arbitrage condition prevails. A leading advocate for the no-arbitrage case is Stephen Ross. He summarizes the case as follows: [16]

> I, for one, never thought that people—myself included—were all rational in their behavior. To the contrary, I am always amazed at what people do. But, that was never the point of financial theory.
>
> The absence of arbitrage requires that there be enough well financed and smart investors to close arbitrage opportunities when they appear . . . *Neoclassical finance is a theory of sharks and not a theory of rational homo economicus, and that is the principal distinction between finance and*

> *traditional economics*. In most economic models aggregate demand depends on average demand and for that reason, traditional economic theories require the average individual to be rational. In liquid securities markets, though, profit opportunities bring about infinite discrepancies between demand and supply. Well financed arbitrageurs spot these opportunities, pile on, and by their actions they close aberrant price differentials. Rational finance . . . has worked very hard to rid the field of its sensitivity to the psychological vagaries of investors. (Emphasis added.)

Arbitrage is the purchase and sale of the same or equivalent security in order to profit from price discrepancies. Naturally, arbitrage has many flavors. In its purest form, arbitrage is buying and selling an identical asset for profit, a riskless venture. Event-driven arbitrage, a riskier venture, includes purchase and sales of the company securities involved in a merger or acquisition. Statistical arbitrage uses past asset price relationships to seek investment opportunities. Finally, arbitrageurs also get responsibility for driving out *any* price inefficiency—or profit opportunity—in the market. Since the first forms of arbitrage are relatively rare, markets require the latter types to stay efficient.

We do not question that markets are highly competitive and that investors seek profit opportunities. As Sanford Grossman and Joseph Stiglitz (1980) point out, there must be "sufficient profit opportunities, i.e., inefficiencies, to compensate investors for the cost of trading and information-gathering." [17] While they argue that there *are* some returns for investors, they suggest that the rewards investors gather are commensurate with the costs they bear. Investors clearly seek and exploit obvious profit opportunities (which is why they are so rare).

There's also no question that some investors have greater influence than others, if only because they have access to more capital. Practically, the no-arbitrage assumption is useful as a first-order approximation of reality. But the assumption that some, instead of all, investors are rational remains fundamentally problematic.

Jack Treynor (1987) cites two conceptual problems. First, as arbitrageurs expand their positions to capture price-to-value discrepancies, portfolio risk rises faster than portfolio demand. After a point, adding to the position is irrational for a rational, risk-adverse investor. Second, and more basic, the argument "assumes that those investors who are right know they are right, while those who are wrong know they are wrong—an unlikely state of affairs."[18]

In addition, as a practical matter the arbitrageurs simply fail to act at critical junctures in markets. The events surrounding the 1998 collapse of Long Term Capital Management (LTCM) provide a recent example. Sociologist Donald MacKenzie notes: [19]

> As "spreads" widened, and thus arbitrage opportunities grew more attractive, arbitrageurs did not move into the market, narrowing spreads and restoring "normality." Instead, potential arbitrageurs continued to flee, widening the spreads and intensifying the problems of those who remained, such as LTCM.

Our very brief discussion of the rational agent and no-arbitrage arguments in support of market efficiency reveal weak underlying assumptions and, much more damaging, predictions that the empirical facts refute. None of this is to say that it's easy to outwit markets. Both approaches imply that most investors have little or no chance of systematically beating the market, a point difficult to dispute.

If the major conclusion of the rational agent and no-arbitrage approaches makes sense, why look elsewhere? We contend that the second approach to understanding market efficiency (the aggregation of investors with independent errors) provides the most promise, even though it has been largely dismissed or ignored by economists—including the behavioral finance crowd. [20]

The Wisdom and Whims of the Collective

To my students a pattern implied a planner in whose mind it had been conceived and by whose hand it had been implemented. The idea that a city could acquire its pattern as naturally as a snowflake was foreign to them. They reacted to it as many Christian fundamentalists responded to Darwin: no design without a Designer!

Herbert A. Simon
The Sciences of the Artificial [21]

The aggregation of investors is an example of a complex adaptive system. All complex adaptive systems have three features in common. First is a group of heterogeneous agents with local information. The heterogeneity arises from varying decision rules, which evolve over time. Second is an aggregation mechanism that leads to emergent behavior. An example of aggregation is the New York Stock Exchange's double-auction market. Finally, there is a global system—in our case, the stock market.

One of the key lessons of complex adaptive systems is that you can't understand the whole by adding up the parts. The whole is greater than the sum of the parts. As a result, reductionism doesn't work.

This is crucial because many people attempt to understand the markets by talking to individuals. If markets are an emergent phenomenon, individual agents will provide little or no understanding of the workings on the market level.

We will review some of the work on collectives, starting with social insects, moving on to simple human examples, experimental economics, and decision markets. We'll then discuss how these ideas apply to the stock market, and how the burgeoning behavioral finance field fits into the picture.

Social insects, including ants and bees, give us a wonderful example of complex adaptive systems at work and demonstrate how collectives can function effectively without leaders. As Thomas Seeley writes in his delightful book, *The Wisdom of the Hive*: [22]

> The most thought-provoking feature of a honey bee colony is its ability to achieve coordinated activity among tens of thousands of bees without central control.
>
> Coherence in honey bee colonies depends . . . upon mechanisms of decentralized control which give rise to natural selection processes . . . analogous to those that create order in the natural world and in the competitive market economies of humans.

Our discussion begins with the animal world for three reasons. First is to show that collectives can solve complex economic problems in nature without leaders and with local information only. [23] Second, we want to underscore how this decentralized notion runs counterintuitive to our deeply human desire to link cause and effect. Notwithstanding the rise in markets over the last few hundred years, the vast majority of human economic activity occurs inside businesses and other organizations where cause and effect remains reasonably clear. [24]

Finally, the results of evolutionary processes often mimic textbook predictions. Writes neuroscientist Paul Glimcher, "there is a significant amount of evidence suggesting that when we can identify what constitutes an optimal solution, animals come remarkably close to achieving those optimal solutions." [25] (You could say that natural selection acts as an arbitrageur, albeit over very long time scales.)

A wonderful assimilation of the work on collectives is James Surowiecki's *The Wisdom of Crowds*. Surowiecki shows how a collection of individuals can outperform experts in case after case. Significantly though, Surowiecki makes some careful distinctions. First, he specifies the conditions under which collectives work well, including diversity, independence, and aggregation. We prefer to collapse the first two and add incentives.

Collectives tend to outperform individuals when you have:

- *Diversity*. Investors have diverse decision rules. Investors take information from the environment, combine it with their own interaction with the environment, and derive decision rules. Various decision rules compete with one another based on their fitness, with the most effective surviving. This process is adaptive.[26] Investors differ in their information, time horizons, and approach (e.g., technical versus fundamental).
- *Aggregation mechanism*. Markets provide a generally effective mechanism for aggregating disparate views. However, aggregation requires sufficient information.
- *Incentives*. Collectives work better when the individuals have some incentive to be right. These incentives need not be monetary.

Second, Surowiecki specifies the types of problems where collectives tend to do better than experts. Experts generally outperform collectives in closed systems. For example, an airplane pilot is likely to be more effective flying a plane because flying consists mostly of rule-based procedures. But when the problem has sufficient complexity, collectives consistently outperform experts.

Let's look at some examples of how collectives solve problems.

The first set of problems collectives solve well is estimating current states—be it how many jelly beans are in a jar, the best path through a maze, or the location of a missing item.

One example of this current-state problem solving is crater classification. In 2000, NASA launched the Clickworkers program to test whether distributed human volunteers were willing and able to classify and mark Mars craters.[27] Over a six-month period 85,000 people visited the web site and submitted almost 2 million crater-marking entries. While the participants were diverse, they first had to take a brief tutorial.

The result? The website reports that "the automatically-computed consensus of a large number of clickworkers is virtually indistinguishable from the inputs of a geologist with years of experience in identifying Mars craters." Notwithstanding limited experience and varying backgrounds, the program found success. Even worries about outliers were misplaced: the site notes that the "frivolous inputs" the project received were "easily weeded out."

Not all examples of collective problem solving are new. In *Moby-Dick*, Herman Melville mentions that Navy lieutenant M.F. Maury used collectives to track the movement of sperm whales. The primary goal of Maury's 1851 book, *Explanation and Sailing Directions,* was not whale tracking but "to put within reach of the young and inexperienced mariner, a summary of the experience of thousands of voyages."

How Maury helped sailors was "to point out those tracks on the great ocean, where the results of carefully collated observations, selected from many and divers [sic] sources, show where you are most likely to find fair winds and favorable currents."[28] While apparently never completing the work on whales, Maury grasped the value of aggregating diverse experiences to find optimal sailing paths.

One objection to these illustrations, as well as some that Surowiecki uses, is their perceived failure to address fundamental economic issues. In 2002, the Nobel committee awarded a prize in economic sciences to Vernon Smith "for having established laboratory experiments as a tool in empirical economic analysis." Smith has led the movement in experimental economics, a means to test outcomes under controlled conditions.

Experimental economics remains controversial because many of the experiments are deemed too unrealistic (for example, students instead of business people serve as subjects) or too simple (the real world is much messier than what the experiments can reflect). Notwithstanding these criticisms, experimental methods inform us of at least two significant principles. First, markets can attain competitive equilibrium with surprisingly weak assumptions about agent knowledge. Second, bubbles and crashes occur under certain circumstances.[29]

As a young professor at Purdue, Smith set up a class experiment to "build the strongest possible case against the Law of Supply and Demand." The results of his experiment "stunned" him: he found that the market worked much as the economic textbooks claimed it should.[30]

This led to attempts by Smith, and others, to test the "Hayek hypothesis"—named after the 20th century Austrian economist Friedrich Hayek—which states that "strict privacy together with the trading rules of a market institution are sufficient to produce competitive market outcomes at or near 100% efficiency." Summarizing a substantial body of research, Smith writes, "The experimental evidence . . . provides unequivocal support for the Hayek hypothesis." [31]

Still, the notion of markets as an information aggregation mechanism does not sit comfortably with most classically trained economists. Smith observes: [32]

> The vast majority of economists in the main stream of British and American economic thought have not accepted, indeed have been openly skeptical of Hayek's claim that decentralized markets are able to function with such an extreme economy of information.

So how much knowledge do investors need to get an efficient result? In an often-cited paper, Dan Gode and Shyam Sunder (1993) suggest the market mechanism itself is more relevant than the intelligence of traders in achieving equilibrium. Even traders with very simple rules can generate efficiency: [33]

> Allocative efficiency of a double auction market derives largely from its structure, independent of traders' motivation, intelligence, or learning. Adam Smith's invisible hand may be more powerful than some may have thought; it can generate aggregate rationality not only from individual rationality but also from individual irrationality.

Note that these experiments attain efficiency without assumptions of investor rationality or arbitrageurs.

Just as experimental economics provided some insights about the mechanisms behind market efficiency, it also offered glimpses into why markets depart from efficiency—bubbles and crashes.

The experiments suggest two factors that contribute to bubbles. The first is momentum. Markets combine negative feedback (arbitrage) and positive feedback (momentum). Experiments show that when prices start below intrinsic value and rise, the price momentum can carry them beyond proper value.

The second factor is the cash availability. Making more cash available to investors increases the likelihood and size of bubbles. Also, bubbles tend to pop rather than deflate slowly. [34]

So experimental markets show results that appear consistent with the real world: markets are generally efficient but periodically go through bubbles and crashes. Do these experimental results translate into the field? [35]

Decision markets, also known as prediction markets, are relevant progeny of experimental economics and take us a step closer to the stock market. Unlike the collective wisdom examples that estimate current states, decision markets make predictions about the future. Online markets include the Hollywood Stock Exchange (www.hsx.com), BetFair (www.betfair.com), Intrade (www.intrade.com) and TradeSports (www.tradesports.com). Since these are typically winner-take-all markets, the price reflects the probability of an outcome. [36]

The best-known decision market is the Iowa Electronic Markets (IEM, www.biz.uiowa.edu/iem). In the four U.S. presidential elections through 2000, IEM predicted the vote percentages with an absolute average error nearly 30% less than that of national polls. [37] Both the IEM and NewsFutures (www.newsfutures.com) markets accurately predicted the outcome of the 2004 U.S. election.

Another online market, Centrebet, (www.centrebet.com) provided keen insight into Australia's 2004 Prime Minister elections. On the eve of the election, the news polls had the candidates running neck-and-neck, while the prices on Centrebet strongly suggested a John Howard victory. Howard won easily. [38]

These are not isolated examples. In their survey of prediction markets, Justin Wolfers and Eric Zitzewitz (2004) show that "market-generated forecasts are typically fairly accurate, and that they outperform most moderately sophisticated benchmarks." [39]

While decision markets generally use real money and have a double auction market structure, they remain substantially different than stock markets for at least two reasons. First, these markets generally deal with discrete outcomes. Second, these contracts have finite time horizons. In contrast, stock markets are continuous and perpetual. As a result, you are less likely to see speculation in a decision market because results occur within a defined period.

We can pause at this point and consolidate the message. A survey of collective problem solving—from social insects to state estimation to experimental economics to decision markets—reveals that when *certain conditions are in place*, collectives tend to be very effective (or efficient). We can achieve many of these results with surprisingly simple assumptions about agent knowledge or behavior. While many of these approaches do not preclude arbitrageurs, none of them require arbitrageurs to achieve efficiency.

How does behavioral finance fit into this picture? We can think of behavioral finance on two levels: individual and collective. The individual level focuses on how people behave in ways that do not conform to economic theory and how they are consistently subject to biases arising from the use of heuristics. Many of the ideas on suboptimal individual behavior are part of Daniel Kahneman and Amos Tversky's prospect theory.[40]

The collective level deals with how people interact with one another, or more accurately how people change their decision rules based on the influence of others. The collective encompasses not only the wisdom of crowds, but also the whims of crowds: particularly the genesis of fads, fashions, information contagions, and herding.[41]

When we look at market efficiency through the complex adaptive system lens, we should clearly focus on collective behavior. Behavioral finance literature and the business world frequently confuse the distinction between individual and collective behavior. We must very carefully avoid extrapolating individual irrationality to market irrationality. The second need not follow from the first.

The behavioral finance attacks on the efficient market hypothesis largely seek to discredit the first and third arguments for market efficiency: rational agents and the no-arbitrage assumption. Certainly the behavioral finance work has corroborated what every aware human knows: individuals are not rational. The case against agent rationality is really a straw man, because no one literally believes the rational agent argument. Indeed, neoclassical finance has retrenched to the no-arbitrage theory.[42]

More recently, the behavioral finance arguments have targeted no arbitrage on the basis that arbitrage in the real world has many imperfections. Transaction costs, risks, a lack of substitute securities, and noise traders can all undermine the arbitrageur's activities. The behavioral finance school is careful about claiming that the inefficiencies they see are systematically exploitable. They are reasonably content in the claim that asset prices do not always reflect fundamental value.[43]

The behavioral camp doesn't have much to say about the second path to efficiency—the uncorrelated errors of investors. But where there are comments, they tend to be dismissive. Shleifer rebuffs the wisdom of crowds argument in one fell swoop:[44]

> It is this argument that the Kahneman and Tversky theories dispose of entirely. The psychological evidence shows precisely that people do not deviate from rationality randomly, but rather most deviate in the same way.

Shleifer overstates his argument. *While investors may deviate from rationality in the same way, it doesn't mean they won't err independently.* Take, for example, overconfidence. Researchers have demonstrated quite conclusively that individuals are overconfident in their own capabilities. Yet if degrees of overconfidence are spread randomly across the buyers and sellers of a security, we have no reason to believe the effects won't offset one another.

An analysis of market efficiency on the collective level proves more fertile than studying individuals. The dynamics shift from how individuals behave to how individuals behave when they are with, or can observe the behavior of, others.

While a full discussion of social psychology is beyond our scope, a few concepts can provide relevance in understanding how collectives might violate one or more of the conditions of the wisdom of crowds:

- *Imitation*. Most investors view imitation with some misgiving (belying their often-imitative actions). But imitation can be rational if someone else has more information than you or if you are trying to minimize tracking error to preserve assets. We know humans innately desire to be part of a crowd. Imitation is one of the prime mechanisms for positive feedback. [45]
- *Network theory*. In recent years scientists made great strides in understanding how we interact with one another. Social networks form the backbone across which ideas travel. Adoption thresholds—our willingness to embrace a new idea—and the small world effect are important concepts here. [46]
- *Information cascades*. Cascades, which include booms, fads, and fashions, occur when people make decisions based on the actions of others rather than on their own private information. Cascades often result from a small initial stimulus. Such cascades occur relatively rarely, and the public widely recognizes them only after the fact. [47]
- *Nonlinearity*. Most ideas and technologies diffuse along an S-curve with a nonlinear rate of adoption. This is a more formal statement of the colloquial idea of the tipping point. Since humans tend to extrapolate recent results, this nonlinearity can lead to market mispricing. [48]

This discussion of group behavior points to where the violation of market efficiency conditions will most likely occur. Studies show that humans (and other species) get caught up in positive feedback and become almost purely imitative, causing a diversity breakdown. If valid, this idea of diversity breakdowns suggests the risk of sharp price changes is *endogenous* to markets, versus the general assumption that risk is *exogenous*.

We argue that diversity breakdowns are the exception not the norm (which is why almost all books on the "madness of crowds" start with the Tulip Mania and South Sea Bubble, events that occurred centuries ago). On the heels of one of the great manias of all-time, it's hard to deny that manias exist and it's even harder to fit them comfortably into an efficient market framework.

Diversity breakdowns often lead to significant asset price changes. The largest of these in recent memory is the 1987 crash, a day when the S&P 500 plunged 20.6%. It's difficult to see how a 20%-plus change in prices in a single day is consistent with either the rational agent or the no-arbitrage theories. In his discussion of the 1987 crash, finance father Merton Miller allowed the work of Benoit Mandelbrot, a polymath best known for his development of fractal geometry and a staunch critic of standard theory. [49]

To summarize the argument to this point, the wisdom of crowds best explains how we achieve market efficiency. Not only does this approach have a substantial track record in nature and in solving other problems, it achieves its results with relatively relaxed assumptions about agent rationality (not even a small percentage of agents need be rational).

The mechanism has the additional feature of being consistent with social psychology in showing how markets get inefficient when they violate one of the wisdom of crowds conditions. The most likely condition to be compromised is investor diversity, and the mechanisms to understand information cascades are improving rapidly.

Conceptualizing markets as a complex adaptive system leads to some stylized predictions. These include:

- *Markets are generally efficient*. We expect few individuals to generate excess returns over time. The facts certainly support this prediction.
- *We should see active trading*. Since investors have heterogeneous decision rules, active trading—especially surrounding important news developments—is what you would expect.
- *We will see large price changes*. This approach suggests that significant price movements are inherent in the system because of diversity breakdowns. Risk and reward are not linearly related. This prediction fits the facts well.

We now turn away from *how* markets are efficient (or inefficient) and focus on *what* the market's statistical properties look like.

Statistical Properties of Markets

The risk-reducing formulas behind portfolio theory rely on a number of demanding and ultimately unfounded premises. First, they suggest that price changes are statistically independent from one another . . . The second assumption is that price changes are distributed in a pattern that conforms to a standard bell curve.

Do financial data neatly conform to such assumptions? Of course, they never do.

Benoit B. Mandelbrot
A Multifractal Walk Down Wall Street [50]

An accurate market description is an important step in developing a new theory for how markets work. Of course, this notion is constant in the evolution of ideas. (Perhaps no better example exists than our understanding of the solar system.) As Benoit Mandelbrot has argued, "Failure to explain is caused by failure to describe." [51]

Most academics describe markets using mean/variance efficiency, which paves the way for a host of robust statistical tools. Most of these tools, including random walk models, assume a normal distribution of price changes. When investment people throw around terms like standard deviation, alpha, beta, and volatility, they're falling back on a world of normal distributions.

The beauty of the normal distribution is that we can specify a distribution with just two variables, mean and standard deviation. Most investors estimate *ex ante* asset class returns using these terms. Many professional investors and corporate executives use risk and standard deviation interchangeably.

Our discussion of market mechanisms, however, shows that markets periodically witness diversity breakdowns, which lead to large price changes. Further, these price changes fall outside the normal distribution. To state the obvious, these large changes can have a meaningful impact on results—as Long Term Capital Management and other investment firms have learned. Nobel-prize winning physicist Phil Anderson said it well: [52]

> Much of the world is controlled as much by the "tails" of distributions as by means or averages: by the exceptional, not the mean; by the catastrophe, not the steady drip; by the very rich, not the "middle class." We need to free ourselves from "average" thinking.

Benoit Mandelbrot was one of the earliest critics of using normal distributions to explain stock price changes. Mandelbrot summarizes some of his important findings in the Noah Effect and the Joseph Effect.[53]

Named after the biblical ark-building figure, the Noah Effect describes the market's trait of abrupt change or discontinuity—fat tails. Power laws may represent these price series better than normal distributions. The key practical implication is that standard models understate risk.

The Joseph Effect, which harkens to the Hebrew slave who prophesied seven years of feast and famine, relates to the market's tendency to have a long-term memory—for example, a rise in stocks tends to be followed by additional increases. Recent work by other financial economists supports this analysis. [54] Mandelbrot developed new statistical tools to measure both the Noah and Joseph effects.

Notwithstanding the empirical evidence, Mandelbrot's work remains outside mainstream economics. Writes Mirowski, "the simple historical fact is that [Mandelbrot's economic ideas] have been by and large ignored, with some few exceptions . . . which seem to have been subsequently abandoned by their authors." [55]

One example of Mirowski's point is the evolution of Eugene Fama's work, widely considered the father of efficient markets. His early papers provide some of the most convincing empirical proof that normal distributions do not apply. In his 1965 *Journal of Business* paper he writes: [56]

> In previous research on the distribution of price changes the emphasis has been on the general shape of the distribution, and the conclusion has been that the distribution is approximately

> Gaussian or normal. Recent finds of Benoit Mandelbrot, however, have raised serious doubts regarding the validity of the Gaussian hypothesis . . . The conclusion of this paper is that Mandelbrot's hypothesis does seem supported by the data.

Going forward, Fama seems much less interested in the issue of price change distributions and more focused on whether or not anyone can beat the market. From his 1965 *Financial Analysts Journal* article, "The empirical evidence to date provides strong support for the random walk model." [57]

Fama's emphasis shifted away from the shape of the distribution towards the independence of price changes, which is all the random walk asserts. By the 1960s we had clear and sufficient evidence to contemplate the implications of non-normal distributions for real-world applications like risk management.

None of this is to say that practitioners and academics don't understand how the real world works. Practitioners patch up models to capture observable empirical features. Rather than dismiss the standard theory altogether, most academics are content to add patches to the existing theory. This approach has the additional feature of rewarding the mathematically fluent.

Examples of theory patching include Black's "noise" traders, generalized auto-regressive conditional heteroskedasticity (GARCH) models, jump diffusion models, and Fama and French's multifactor risk model.[58] Each of these models departs from standard theory in an effort to provide more accurate predictions.

While the view of markets through the lens of complex systems is relatively new, three factors make us optimistic. First, a number of agent-based models have successfully replicated the features of the market. Some of these models show two regimes: efficient and inefficient—complete with booms and crashes. While necessarily simple, these *in silico* models lend support to the view that the interaction of heterogeneous agents can generate realistic efficient and inefficient outcomes. [59]

Second, scientists have found statistical techniques useful in other social science applications. One illustration is Robert Axtell's work on Zipf's Law and company size. Zipf's Law accurately explains the relationship between company size and frequency in the United States. [60]

Finally, some researchers claim that stock market crashes have a statistical signature: log periodicity. Whether this theory is valid remains to be seen. Importantly, it offers specific predictions about when there is an elevated probability of a crash. [61]

Conclusion

The efficient market hypothesis offers a practically sound prescription: most investors are best served investing in low cost, passive index funds. Overwhelming evidence, accumulated over many decades, shows a consistent inability of most active investment managers to add value.

Active investment managers seeking excess returns should have a thoughtful investment process that logically starts with a view on how and why market mispricings can occur. Of the three approaches to explain market efficiency, only the complex adaptive systems perspective comfortably accommodates what we see in the real world: heterogeneous investors create markets, which remain mostly efficient but periodically go to excesses. The rational agent and no-arbitrage approaches, while valuable constructs, are not true mechanisms and fail to explain real market behavior in many important respects.

The ultimate goal of an active investor is to buy securities in anticipation of an expectations revision. In a future piece, we will address the logical question: how can we use these ideas to generate excess returns in the stock market?

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