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UNLOCKING THE ECONOMY OF THE MIND

Researchers are using new approaches and tools to try to reconcile the differences between neoclassical and behavioral finance.

BY BEN BARIS,
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MIT SLOAN SCHOOL OF MANAGEMENT FINANCE PROFESSOR Andrew Lo traces his interest in economics to a seemingly unlikely source: science fiction author Isaac Asimov. As a student at New York's Bronx High School of Science in the mid-'70s, Lo was a fan of Asimov's *Foundation* series, whose central character, Hari Seldon, develops a fictional field of study called psychohistory that combines history, psychology and statistics to predict the actions of a large group of people. "The idea that you couldn't tell what an individual was going to do but that you could say with more certainty what a population of individuals might do struck me as being quite plausible," explains Lo, who graduated in three years from Yale University with a BA in economics in 1980 and earned his Ph.D. from Harvard University four years later at the age of 24. "That's exactly what the field of financial economics is all about."

Today academics like Lo are drawn to finance because it deals with very practical real-world problems such as what an asset is worth or where to invest capital. For those with a strong quantitative bent — Lo, for example, originally intended to major in biochemistry, math and physics at Yale — finance is especially attractive as a laboratory in which they can develop and test their theories. But for much of the history of finance, which has been around for as long as there have been markets, serious economists largely ignored the field. It didn't start to attract the attention of theoreticians until the 1960s and '70s.

"Prior to then finance had been pretty much the purview of busi-

ness schools, which were pretty nontheoretical places with lots of institutional material and rules of thumb," says William Sharpe, 78, who is now retired after a long career teaching finance at Stanford University. "Then the economists invaded finance, asking questions about why people did things in a certain way and followed certain rules."

Sharpe was among a band of young economists with revolutionary ideas for introducing uncertainty into finance and using computers to crunch data and run regression analyses. In 1964 he published a groundbreaking paper on the Capital Asset Pricing Model, which reduced to a simple formula the relationship between risk and return that most market participants already intuitively knew: To achieve higher returns, investors need to take on greater risks. CAPM introduced alpha (excess return) and beta (a measure of market risk) to the investment lexicon and became one of the pillars of modern, or "neoclassical," finance. It also earned Sharpe the 1990 Nobel Prize in economic sciences. That year he shared the award with Harry Markowitz, the father of Modern Portfolio Theory, and Merton Miller, best known for his work on corporate finance.

The decision by the Nobel committee to recognize Markowitz, Miller and Sharpe brought legitimacy to the field of finance. It was also a key endorsement of the major assumptions underpinning modern financial theory — that markets are efficient and that investors have rational expectations and can process information quickly and accurately. The Efficient Market Hypothesis, introduced in 1970 by University of Chicago Booth School of Business finance professor Eugene Fama, and CAPM suggest that it is difficult, if not impossible, for active investors to beat the market.

Not surprisingly, the asset management industry has embraced Modern Portfolio Theory, which is basically a user's guide on how to construct an "efficient," or well-diversified, portfolio, maximizing the investment return for a given level of risk. Fund managers, however — apart from Vanguard Group and a few other companies that have built their businesses on indexing — have not embraced the notion that markets are efficient. For support, they can turn to the field of behavioral finance, which Santa Clara University finance professor Hersh Shefrin defines as "the application of psychology to the study of financial decision making and financial markets."

Behavioral finance traces its roots to the research of Israeli psychologists Daniel Kahneman and Amos Tversky, who through a series of experiments starting in the late '60s showed that people are not always rational when making decisions and make mistakes in judgment because of heuristics and cognitive biases. By the 1980s reports of anomalies — including unexplained investor and market behavior as a result of the effects of loss aversion, mental accounting, overconfidence and overreaction — began appearing in professional journals, by economists such as Chicago's Richard Thaler (then at Cornell University) and Yale's Robert Shiller, calling into question the dogma of rational behavior.

"It was [British economist] Alfred Marshall who said over 100 years ago that economics is not an exact science," Shiller, 66, explains. "The problem is, it's the study of people. There's some mysterious extra that comes with human will and intention. But it's very hard to reduce to a formula."

From the outset neoclassical economists rejected the behavioral school. "There's no behavioral theory; it's all just inefficient markets," says Fama, 73. "It's a big blanket, not a theory of its own."

Unless there's a coherent theory that can be subjected to tests, there's nothing to replace [the Efficient Market Hypothesis] with."

The neoclassical finance camp has had a strong supporter in Boston University finance professor Zvi Bodie, co-author with Alan Marcus and Alex Kane of *Investments*, the textbook used by most U.S. MBA programs. Although the book, now in its ninth printing, devotes one chapter to behavioral finance, Bodie is clearly not a believer. "Shiller and all those people are basically wrong," he says. "They know it but won't admit it."

The debate — some would say battle — between the neoclassical finance school and behavioral theorists has yet to be settled. That's because one critical factor has not been addressed by either camp, posits Paul Woolley, senior fellow at the London School of Economics. In *The Future of Finance*, published by the LSE in 2010, Woolley calls for "a science-based, unified theory of finance... that retains as much as possible of the existing analytical framework and at the same time produces credible explanations and predictions."

He is looking for a solution in the principal-agent relationship.

Woolley, along with his colleague Dimitri Vayanos, a professor of finance at the LSE who has taught at both the MIT and Stanford business schools, believes that capital market booms and crashes have discredited the Efficient Market Hypothesis. "The idea that the markets are efficient is 40 years old," says Woolley. "That's no longer credible. We're offering an alternative paradigm." Specifically, Woolley

and Vayanos assert that private, individual investors do not set prices because they delegate virtually all of their investment decisions to financial intermediaries, or agents. Delegation creates an agency problem.

After 25 years as partner, then chairman, of asset manager GMO's London office — which he opened — Woolley in 2007 established the Paul Woolley Center for the Study of Capital Market Dysfunctionality at the LSE, naming Vayanos as director. Through this institution Woolley is offering a new theory of finance that he hopes will produce credible explanations and predictions for market behavior. "Two things happen if you introduce the principal-agent problem," says Woolley, 73. "One, you get asset mispricing, as markets are momentum-driven. Two, the agents are in a position to capture excess returns that should go to the asset owners."

Momentum — the tendency of a stock or market to continue in the same direction it has recently been moving — is incompatible with efficient markets, argues Woolley, and has been difficult to explain, even by the likes of Fama. In 1993, Fama and colleague Kenneth French (now a finance professor at Dartmouth College's Tuck School of Business) introduced a "three-factor model" to explain the momentum and value effects that contradict the Efficient Market Hypothesis. But Vayanos has a different take on it. He is currently working on a new model for asset pricing that incorporates how individuals choose their asset managers and how money flows from manager to manager. The problem, as Vayanos sees it, is that

A (Non)Random Walk Through Financial History

Part I: The Quants Take Over

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The dawning of the age of modern finance:

Harry Markowitz, a graduate student at the University of Chicago, publishes his Ph.D. thesis, "Portfolio Selection," in the *Journal of Finance*. With one stroke, Modern Portfolio Theory is born and with it a quantitative basis for not putting all your eggs in one basket.

The first inkling of the random walk:

British statistics professor Maurice Kendall publishes "The Analysis of Economic Time Series, Part I: Prices," expressing surprise at his finding that stock prices fluctuate without any predictable pattern. Financial economists are also shocked; later they realize that random price movements are signs of an efficient market.

Markowitz writes the book:

While spending a year at the famed Cowles Foundation for Research in Economics — on leave from his job at RAND Corp. — Markowitz expands his theory of covariance and diversification in *Portfolio Selection: Efficient Diversification of Investments*. He then abandons finance and returns to operations research at RAND.

Unsung hero: Jack Treynor, longtime editor of the *Financial Analysts Journal*, scoops William Sharpe by writing "Toward a Theory of Market Value of Risky Assets," about capital asset pricing, but he does not publish it. Along with Sharpe, he realizes the value of the Capital Asset Pricing Model for rating money managers.



The price is right:

Sharpe, who studied under Markowitz and will share a Nobel Prize with him, does publish a paper on capital asset pricing, "Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk," achieving fame and glory for the CAPM.

Noble cause: University of Chicago economist Paul Samuelson lays the groundwork for the breakthrough random walk and efficient-market hypotheses with "Proof That Properly Anticipated Prices Fluctuate Randomly," one of dozens of papers he will publish in his lifetime. In 1970 he becomes the first American to win the Nobel Prize in economic sciences.



SAMUELSON: DONNA COVENEY/MIT/VIA BLOOMBERG NEWS

investors have incomplete knowledge of their managers. So when an investment fund is underperforming, investors — who can't tell if the manager is incompetent or prudently avoiding overpriced stocks — take away their money and give it to managers who are outperforming. In that way, the overpriced securities held by the outperforming managers are driven higher. This mispricing is not

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— Andrew Lo, MIT Sloan School of Management

caused by investors' irrationality or stupidity, says Vayanos, but rather by their imperfect knowledge of the agents managing their money.

"These flows can account for the momentum and value effects," he adds. "Our agency-based view says maybe everything can be understood in a fully rational world."

MIT's Lo spent the first ten years of his career trying to explain away the conflict between the rational theory he had been taught

in graduate school and the behavioral finance literature he read afterward. Part of that time he was an assistant finance professor at the University of Pennsylvania's Wharton School, where he and fellow professor A. Craig MacKinlay looked at every market anomaly that had been documented to see whether there was some kind of empirical explanation for them. They couldn't find any. "I tried all sorts of ways of explaining away the results, but ultimately I realized it would be a lot easier simply if we understood that the Efficient Market Hypothesis has limitations," Lo says.

With that in mind, he began reading through the literature on evolutionary biology, neuroscience and psychology to explore what those limitations might be. The result is what Lo calls the Adaptive Markets Hypothesis, which as the name suggests applies the principles of evolution — competition, adaptation and natural selection — to financial decision making. As Lo explains, financial markets are an example of an adaptive response to a particular environmental challenge. "If we're going to maximize our chances for survival, having financial markets is a lot better than not having financial markets," he says. "It is part of evolution."

The Adaptive Markets Hypothesis attempts to reconcile the contradictions between efficient-markets theory and behavioral finance by focusing on how people adapt to a changing environment, using both logical reasoning (which takes place in the prefrontal cortex of the brain) and more-primitive responses such as the fight-or-flight

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Measure by measure:

Sharpe expands on the CAPM by introducing "reward-to-variability" — also known as the Sharpe ratio — to measure risk-adjusted returns, in a paper titled "Mutual Fund Performance" in the *Journal of Business*. It will become a key performance measurement in asset manager selection, assessing the ability to deliver alpha.

Big league: Athletic quant Eugene Fama shakes up the previously sleepy field of finance by introducing the Efficient Market Hypothesis in "Efficient Capital Markets: A Review of Theory and Empirical Work."



Re-CAP:

Fischer Black, who bounced between academia and industry multiple times before settling in at Goldman Sachs in 1984, develops a zero-beta CAPM.

Psyched out: The first psychologist to put in print a work on behavioral finance, Paul Slovic publishes "Psychological Study of Human Judgment: Implications for Investment Decision Making" in the *Journal of Finance*.



Time out: MIT finance professor Robert Merton adds to the CAPM with his continuous time, or intertemporal, finance theory.

The price is right: Black and Myron Scholes publish "The Pricing of Options and Corporate Liabilities," setting the stage for an onslaught of financial instruments and investment strategies.

Well behaved:

Israeli-born psychologists Daniel Kahneman (pictured below) and Amos Tversky publish "Judgment under Uncertainty: Heuristics and Biases," a seminal work in behavioral theory.



More options: Then-Wharton professor Stephen Ross invents the arbitrage pricing theory, adding increased functionality to the CAPM with multiple factors that influence returns.

impulse when someone is threatened. (The latter is characterized by a series of almost instantaneous physiological changes, including the release of glucose into the bloodstream, increase in blood flow and acceleration of reflexes.) Understanding the interaction between both kinds of decision-making mechanisms is critical: "The behavioral biases that psychologists and behavioral economists have documented are simply adaptations that have been taken out of their evolutionary context," Lo wrote in a recent article for the *Financial Analysts Journal*. "Fight-or-flight is an extremely effective decision-making system in a street fight but is potentially disastrous in a financial crisis."

According to Lo, market efficiency changes over time based on "the relative proportion of market participants who are making decisions with their prefrontal cortexes versus their more instinctive faculties." Similarly, the trade-off between risk and reward changes over time. During periods of fear like the 2008 financial crisis, investors rush into safer assets, which has "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," Lo writes. According to the CAPM, investors should be rewarded, not punished, for taking on more risk.

Lo no longer sounds like a financial economist; his speech is punctuated with words from evolutionary biology, like "survival," "species" and "adaptation." He concedes: "It's getting harder and harder for me to talk to my colleagues because I have a different way

of thinking about it. The way I think about it actually has greater explanatory power, as opposed to people maximizing expected utility, the income shock and where they substitute for other assets. All those theories are wonderful in terms of the precision of the forecasts they produce. The problem is that those forecasts are routinely violated."

WHEN IT COMES TO THE INEXHAUSTIBLE PURSUIT OF knowledge, it's best to attack from all angles. That's why Andrew Caplin, professor of economics at New York University and a self-described man of many hats, has eschewed affixing himself to any one field of economic research. He sees value in collecting and analyzing data from varied sources. The mountainous stacks of papers occupying the desk and bookshelves in his Washington Square Park office indicate as much.

"I like to go where the action and thinking will be effective," says the London-born economist, who has plied his trade in the U.S. since he received a Ph.D. with distinction from Yale in 1983.

This approach toward academia has led Caplin, 56, to conduct research on varying topics, from life-cycle spending to the U.S. housing crisis. Since the early 2000s he has spent much of his time on a relatively new field of study he believes is a treasure trove of data: neuroeconomics, which amalgamates economics, psychology and neuroscience to explore the underpinnings of why and how people make the choices they do.

Caplin is not alone. Researchers at other prominent institutions,

Part 2: The Social Science Invasion

1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995

Ch-ch-changes: The so-called rational investor gets a remake when Kahneman and Tversky inject behavioral psychology into the decision-making process in "Prospect Theory: An Analysis of Decision under Risk." Their article recasts some of the neoclassical economics anomalies within the context of cognitive models that center on individual decisions about the probability of outcomes. The groundbreaking work earns Kahneman a Nobel Prize in economic sciences in 2002. (Tversky died in 1996.)

Decisions, decisions: Does the wording of a choice affect the response? Kahneman and Tversky take a page from cognitive psychology and sociology to prove that it does in "The Framing of Decisions and the Psychology of Choice," published in *Science*. The two found that people are more likely to avoid risk when a situation is framed in a positive fashion and seek risk when it is framed negatively.



Join the party: The American Finance Association invites Santa Clara University professors Hersh Shefrin (top) and Meir Statman to organize the first behavioral finance panel at the group's 1985 annual meeting.

Bi-path: Joining Shefrin and Statman in the behavioral session at the AFA meeting are Werner De Bondt and Richard Thaler (below), who present their paper "Does the Stock Market Overreact?", published in the *Journal of Finance*. The session neatly divides future behavioral finance research into two paths: asset pricing and investor behavior.



Sorted out: Frank Sortino develops Postmodern Portfolio Theory; his Sortino ratio, a variant on the Sharpe ratio, adjusts estimated returns for downside risk, thus differentiating between good and bad volatility.

Brain game: Setting the stage for neuroeconomic research, Bell Laboratories' Seiji Ogawa discovers the blood-oxygenation-level-dependent (BOLD) signal, the technique behind fMRI, which allows for visualization of brain activity by external stimuli.

Third one's a charm: In response to stubborn and persistent anomalies in efficient markets, Fama and Kenneth French introduce the three-factor asset pricing model.

Body-building: In an effort to build a body of literature in behavioral finance, then-Cornell economics professor Richard Thaler publishes *Advances in Behavioral Finance*, a collection of articles and papers. Two years later he moves to the University of Chicago.

including the California Institute of Technology, Duke University, University College London and the University of Zurich, have been drawn to neuroeconomics. The discipline is the natural progression from behavioral finance, the first field to look into the relationship between cognitive biases and asset pricing. Although behavioral finance seeks to reconcile the psychology and economics behind decision making, Caplin says it hasn't provided a full explanation.

"The delight about behavioral is that it never has to say it's wrong," he explains, echoing criticisms from the neoclassical crowd. "It's about the other guys being wrong. You can't win in the

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—Andrew Caplin, New York University

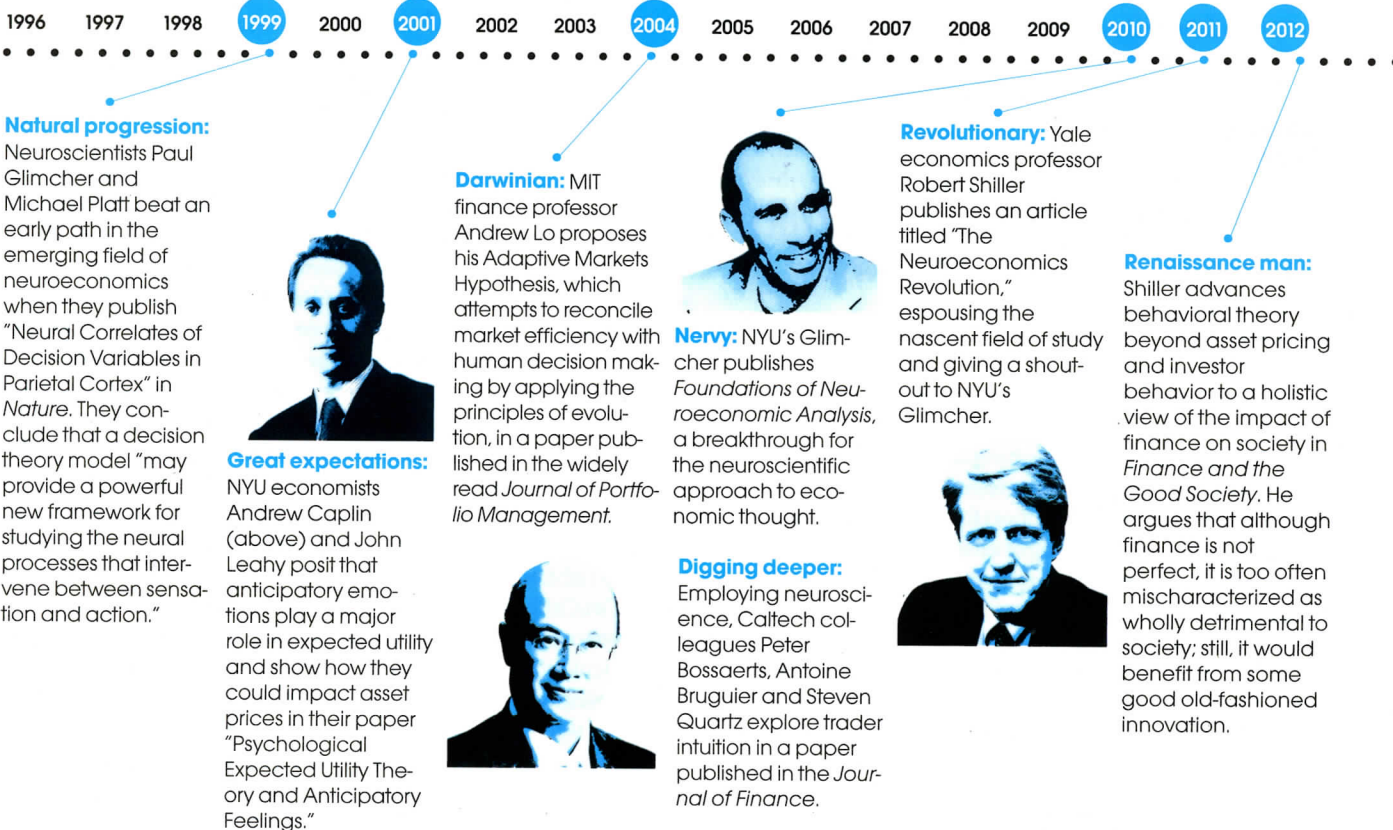
long run this way. What's right? Is there anything you can rule out? Their class of anomalies is infinite."

At the core of a neoclassical finance model like the CAPM is the idea of balancing risk and return. Behavioralists point out

that because humans are not perfect, mistakes are made in this measurement. Although economists have been able to document how biases such as overconfidence or herding may cause a person to miscalculate, they have struggled to come up with empirical evidence to explain why. The addition of neuroscience to the fold allows researchers literally to take a peek inside the brain to view risk and return in real time as investors make choices.

One of the keys to understanding decision making is the neurotransmitter dopamine. Neurotransmitters are the postal workers of the brain, sending electrical messages across the synapses that connect the organ's tens of billions of neurons. Dopamine can be found in several regions of the brain, playing an important role in the reward pathways reinforcing behavior that brings satisfaction or pleasure. From a physiological standpoint, the release of dopamine in response to an expected return on an investment decision provides useful data for evaluating how people learn and value information. A well-constructed neuroscientific experiment can not only discover that a subject has miscalculated the riskiness of an investment option, it can also pinpoint the area of the brain that was active before, during and after the choice was made.

The promise of neuroscience brought Caplin together with Paul Glimcher, head of NYU's Center for Neuroeconomics. While Caplin is figuratively a man of many hats, Glimcher actually keeps three in his office: two baseball caps imprinted, respectively, with the



words “Economist” and “Psychologist” and a hard hat emblazoned with a capital “N,” for “neuroscientist.” Early in his career, while an assistant professor of neuroscience at NYU, Glimcher, who was trained as a physiologist and a mathematical psychologist, concluded that to further his neurological work on decision making he needed a fuller grasp of the economic theory behind it. So he went across the street to NYU’s economics department and began attending graduate courses, slowly retreading himself as an economist.

Glimcher, 50, was looking for organizing principles of neural activity; Caplin was searching for new ways to measure choice behavior. Seven years ago they started teaching a neuroscience and economics seminar together. Caplin saw that choices by the individual at a microeconomic level were largely being ignored in the macro view of the world. “A fundamental problem for economists is that we’ve been very unimaginative with our data,” he explains. “We don’t understand why we go wrong, and it’s because of the data. A theory of saving is a theory of behavior in every state of the world. Well, we don’t see every state of the world.”

Caplin and Glimcher combined their expertise to come up with an expanded understanding of dopamine, building on the work of University of Cambridge neuroscience professor Wolfram Schultz and others. In the 1990s, Schultz, then at the University of Fribourg in Switzerland, conducted an experiment in which he recorded the neural activity of thirsty monkeys that received drops of juice, preceded by a tone, at irregular intervals. He found that the dopamine neurons fired when the monkeys heard the tone, not when they tasted the juice. “These findings led to the hypothesis that dopamine was encoding the difference between ‘experienced’ and ‘predicted’ reward, or a ‘reward prediction error,’” Caplin and Glimcher wrote in a 2010 article for the *Quarterly Journal of Economics*. The article, which was coauthored by then-NYU colleagues Mark Dean and

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—Robert Shiller, Yale University

Robb Rutledge, was based on experiments using functional magnetic resonance imaging (fMRI) to record people’s brain activity when given lottery choices. By measuring dopamine release, they were able to determine whether prizes were more or less rewarding than expected, providing further support for “the conclusion that reward prediction error-based learning of value occurs in the human brain.”

In Pasadena, 2,800 miles away from the neuronucleus that is NYU, researchers at Caltech have also taken a keen interest in the neurological underpinnings of economic decision making. What started as a collaboration between two like-minded professors has become one of the most notable neuroeconomic research efforts in the world. The two, Colin Camerer, a professor of behavioral economics, and Peter Bossaerts, a professor of economics, management and finance, were able to sneak neuroeconomics into a relatively narrow Caltech curriculum and proceed from there.

A preeminent U.S. research university, Caltech attracts top thinkers. It has produced 31 Nobel Prize winners, almost all in physics, chemistry and physiology or medicine, and has five laureates currently in residence, out of a full-time professorial faculty of 297. With fewer than 1,000 undergrads and a 3-to-1 student-to-teacher ratio, the lowest of any research university in the U.S., Caltech may not seem the obvious choice to join the prominent ranks of a social-science-minded discipline like neuroeconomics. But just as in sports or an orchestra, “talented intense people want to be around talented intense people,” says Camerer, who had earned an MBA in finance and a Ph.D. in decision theory from the University of Chicago by the age of 22. Caltech has six professors working on neuroeconomic research; Antonio Rangel, the most recent addition, heads up the neuroeconomics laboratory.

Camerer joined Caltech in 1994 after teaching stints at the University of Chicago, Wharton and Northwestern University’s Kellogg School of Management, and focused on behavioral game theory for the better part of the next decade. He became interested in neuroeconomics in 2003 when Caltech installed its first fMRI machines. In one of Camerer’s experiments, participants were hooked up to brain scanners and observed during 50-hour-long stock-trading periods in an artificial market. The subjects either wore special goggles with the trading screen illuminated inside the lenses or watched a screen inside the scanner. In another study, a monetary gambling experiment, Camerer used an electroencephalogram (EEG), which measures brain electrical activity, to study the almond-shaped area of the brain called the amygdala, known to be important to loss aversion.

“If you really want to study emotions seriously, you have to measure it biologically,” says Camerer, 52. “New sources of data of some kind, whether it’s experiments or experiments plus neuroscience, are going to be helpful.”

Caltech’s Bossaerts also sees value in fresh data. “I use experimental control to get a better understanding of fundamental issues in finance,” says the Belgian-born 52-year-old, who has a doctorandus degree in applied economics from what is now called the University of Antwerp and a Ph.D. in management from the University of California, Los Angeles. “This goes from the systems level [markets] down to the individual.”

Bossaerts’ interest in market experiments led him to explore empirical tests on theories, including the CAPM, to see which ones held up, and how. The CAPM “lends itself very well to laboratory experiment because it has only one period horizon,” he explains. In these experiments Bossaerts created minimarkets for about 30 participants, who were given an allocation of stocks and cash, as well as expected dividends and possible payoffs, and were provided with a simplified, user-friendly trading system. Bossaerts noticed that while the Markowitz theory behind the model did not hold up, the CAPM on the whole did. “That was our first indication that there is something in this theory that’s right, and there is something completely wrong,” he says.

The Caltech professor’s interest in neuroscience stems from what he sees as the problem with economics in general and finance in particular: They try to explain behavior without understanding the neurological processes that lead to decision making. He also doesn’t like how both neoclassical and behavioral economists view emotions, blaming them for bad decisions and insisting that people need to be emotionless to make good ones. “Just from the point of view of evolutionary biology, this made no sense,” says Bossaerts, echoing

the themes in Lo's Adaptive Markets Hypothesis. "If emotions were indeed bad, we would have been wiped out by 'homo rationalis,' but instead it's we, emotional creatures, that wiped out the others."

Neuroscience is necessary to pick up where other behavioral theories have left off, says Bossaerts, who studies value signals (how much utility the brain assigns to certain stimuli) to explain deviations from a particular theory. "At each point in that valuation process, things may go wrong or may be different from what the standard theory actually predicts," he explains. "I'm trying to understand the algorithms that the brain uses to perceive uncertainty, to learn about uncertainty, to eventually lead to a choice under uncertainty."

Bossaerts hopes this method of understanding the brain will ultimately lead to a revolution in the way economists and finance folks think about choices — not as the maximization of utility but as the outcome of a decision-making process. "The bottom line for finance, and in particular asset pricing, is that it is absolutely true — it works like that," says Bossaerts. "Where it fails very often is that that theory is too tight; it doesn't allow for any mistakes in these expectations."

The insularity of academic disciplines has hindered progress, Bossaerts says. Economists are trained too much like historians, using past knowledge to mold their perceptions. Those in finance are mathematically bound, lean more toward natural philosophy and are not sufficiently experimentally minded. "Decision neuroscience allows us to get out of the straitjacket of revealed preference," he says.

Yale's Shiller agrees. In November 2011 he wrote an article titled "The Neuroeconomics Revolution" in which he explained how "revolutions in science tend to come from unexpected places" and how neuroscience is changing the way people think about economics. Shiller calls for collaboration among social scientists — psychologists, sociologists and economists — as well as among law professors, political scientists and mathematicians, to move the field of finance forward. "You have to have a synthesis," he says. Shiller sees finance theory as "a sequence of little stories that are enlightening, but they end up trailing off and not going anywhere." For example, "the CAPM is a brilliant story, but once you've heard it, there are a lot of contradictions, just as the theory of relativity contradicts quantum mechanics."

MIT's Lo is part of the neuroeconomics revolution. In fact, he has been wiring up traders since the 1990s. "It's all part of the same kind of thrust, which is, we're trying to understand how economic decisions get made, from a biological perspective," he says. "I'm focusing on physiology; [the neuroscientists] are focusing on brain imaging." Most recently, Lo has been working on a version of the CAPM that incorporates evolutionary biology and the biases that behavioral finance has identified. "One of the things that this theory implies is that the risk-reward trade-off that we all know and love is not stable over time," he says. "One of the implications of the Adaptive Markets Hypothesis of the CAPM is that it's not fixed over time. It actually changes over various different circumstances."

If all this sounds a little like Asimov's psychohistory, that's not a coincidence. There's clearly an element of science fiction to the future of finance theory.

"The more we understand about the various elements of decision making, I think the more likely it is that we'll develop a complete picture of how humans behave, and that's really to me the Holy Grail," says Lo. "But unlike the Holy Grail, I think that this is achievable within the next decade or two." ●●