The Human Brain, Markets and Financial Decision Making

Recent breakthroughs in the burgeoning field of neuroeconomics have revealed several important patterns in brain function that may explain investors’ demand for particular assets and make financial decisions more predictable.
experiments about anomalistic patterns already had been seemingly irrational human behavior. Although many separate half of the 20th century, when studies began to be published on Behavioral economics didn't make its appearance until the second in influenced others to focus on this emerging field of research. results earned him one of the first Nobel Prizes, in 1906, and individual cells connected by synapses. Ramón y Cajal's pioneering suggesting that the human nervous system is made up of discrete Modern neuroscience dates to the early 1900s, when a Spanish The Birth of Neuroeconomics

Von Neumann and Morgenstern’s prediction appears to have become reality. Recent breakthroughs in neuroscience have allowed us to quantify pain, gain, happiness and fear — and to discover the factors underlying our behavior. With the emergence of neuroeconomics — a field that connects brain-related neuroscience with economics — the analysis of human choice involving monetary rewards is no longer an abstract task. We have never been closer to understanding the patterns behind people’s financial decisions. Although neuroeconomists still are far from fully understanding how the human brain works, they have uncovered many important patterns in its function that make our financial choices more predictable. This kind of predictability at the brain level is exactly what the financial industry needs in today’s era of Big Data, in which the collected information is so vast that it must be filtered and standardized.

Behavioral economics didn’t make its appearance until the second half of the 20th century, when studies began to be published on seemingly irrational human behavior. Although many separate experiments about anomalistic patterns already had been documented, the first coherent economic decision-making model was presented in 1979, in a groundbreaking paper by psychologists Daniel Kahneman and Amos Tversky titled Prospect Theory: An Analysis of Decision Under Risk. Kahneman (who would receive a Nobel Prize in economic sciences in 2002) and Tversky provided a coherent framework that explained some decision-making biases called heuristics. Their theory highlighted that financial decision making is frame-dependent (it depends on the given context) and humans are prone to loss aversion (losses are much more painful than gains of similar magnitude).

Behavioral economics and neuroscience evolved independently until the early 2000s, when research in each field began to include methods and results from the other. Eventually, this led to the emergence of neuroeconomics. As its name suggests, neuroeconomics combines elements of both disciplines, borrowing methods from neuroscience to explain how economic decisions are made by directly measuring brain activity during situations involving monetary rewards. The literature accumulated so far has provided biological evidence for patterns previously detected by behavioral economics. Studies observing how the human brain processes preferences for risk, expected outcome or delay apply a handful of techniques borrowed from neuroscience.

The most common techniques are related to brain imaging and aim to localize the regions and layers in the human brain that are specifically involved in particular tasks. Region-specific brain activity can be analyzed in three ways: by attaching electrodes to the scalp to measure electrical activity — a method called electroencephalogram (EEG); by measuring blood flow using positron emission tomography (PET); or by measuring blood oxygenation through functional magnetic resonance imaging (fMRI). Using these techniques, researchers have been able to identify and separate the layers in the brain that are responsible for specific tasks (see table, below).

Measuring Up

Here are the most popular methods that researchers use to analyze brain activity.

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<th>Method</th>
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<td>Electroencephalogram (EEG)</td>
<td>Electrodes are attached to the scalp to measure electrical responses to given stimulus.</td>
<td>EEG has high temporal resolution (i.e., it can measure immediate reactions to a given stimulus), it is not expensive, and it is easy to apply, hence accessible to a large number of researchers.</td>
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Other promising areas of research include experiments in which researchers analyze humans with damaged brains and determine how their performance differs from that of humans with normal brains. For healthy subjects a method called transcranial magnetic stimulation (TMS) is often applied: The noninvasive procedure, which uses magnetic fields to temporarily disrupt brain function in specific areas, can create conditions similar to those experienced by people with true brain damage.

The importance of adopting these techniques for economic modeling is underscored by the fact that neuroeconomics has redefined the principles of economics. As California Institute of Technology behavioral economist Colin Camerer and others have noted, the assumption-based “as if” approach made good sense as long as the brain remained substantially a black box. Now, however, scientists can directly locate and measure our brain activity, allowing us to relax assumptions previously defined in economics: The analysis of choice is no longer subject to the standard rationality (making the optimal choice that takes into account all the information related to a problem) and homogeneity (similar preference of different market participants in a given situation) conditions of decision making.

As University of Pennsylvania psychology professor Joseph Kable and New York University neuroeconomist Paul Glimcher have shown, “the subjective value of potential reward is explicitly represented in the human brain.” Their 2007 study found that neural activity (as measured by increased blood oxygenation) in certain regions of the brain is identical to subjective utility, as it reflects preference by predicting choice. This evidence implies that the once-abstract term of “utility” has become an exact, quantifiable measure; through it our choices have become highly predictable in similar situations. From a financial point of view, this direct, “hard-wired” predictability is highly relevant, and its importance will rise as the amount of data collected increases exponentially.

**Neuroscience and Price Dynamics**

Recent findings in neuroeconomics have revealed biological evidence for a large number of patterns that behavioral finance had already noted. The importance of having a fundamental explanation for financial anomalies by analyzing the nerve structure in our brains lies in the fact that our neural system is highly robust in time: Our hard-wired way of perceiving and thinking has evolved to its current form over thousands of years, and is expected to remain mostly unchanged in the future. In fact, studies of our closest primate relatives have shown that some basic decision-making biases emerge when the subject faces risky choices. UCLA economist Keith Chen, and Yale University economists Venkat Lakshminarayanan and Laurie Santos found that in an experiment involving trading for coins, capuchin monkeys demonstrated exactly the same behavioral patterns that had been documented with human subjects. When the primates were given tokens to trade for pieces of food, they behaved in line with reference dependence (outcome distribution presented as a gain is preferred over the same distribution presented as a loss) and loss aversion (riskless outcome is preferred over the same outcome presented as a loss), as described in prospect theory.

When it comes to investing, persistence is a key property of a trading signal. Unlike some well-documented market anomalies, such as seasonality (the January effect or the post-IPO drift), that fade away quickly after they are discovered, biases that are hard-coded in the human brain may survive the test of time. The following examples reveal a small slice of what neuroeconomics might contribute to investments and, in particular, to algorithmic trading through its ability to identify robust patterns.

The first study is connected to the predictive nature of brain imaging in regard to the preference for assets and to the dynamics of risk preference. University of North Carolina neuroeconomist Camelia Kuhnen and Stanford University neuroscientist Brian Knutson provided neural evidence for the well-known pattern of negative autocorrelation, or mean-reversion, in returns. They created a dynamic experiment in which subjects were able to choose from two stocks and a bond in each of ten trials. During the process the subjects were monitored by fMRI, and at the end of each trial they were told about the realized outcome of their previous choice.

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<td>Positron emission tomography (PET)</td>
<td>A small amount of positron-emitting radionucleide is introduced into the body and then moves with blood flow. By measuring its concentration in certain areas, neural activity in those parts can be ascertained.</td>
<td>PET has lower temporal resolution and lower accessibility but compensates for its weaknesses with spatial resolution (i.e., it allows mapping of different brain regions). Nevertheless, it is often avoided because of its invasive nature.</td>
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<td>Functional magnetic resonance imaging (fMRI)</td>
<td>Stimulus-related response is measured by detecting the difference between magnetic properties of the blood flow for changing blood oxygenation.</td>
<td>Similar to PET, fMRI is used for mapping brain regions due to its high spatial resolution, but because it is noninvasive it is growing more popular.</td>
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The authors found that when the subjects held a stock, both the outcome and the cumulative earning had a significant negative effect on the probability that they would subsequently choose another stock. In other words, closing a trial with a gain (or a loss) induces lower (or higher) demand for risky assets, which translates into a price decline (or increase) in a real stock market, thereby creating the familiar mean-reverting pattern.

Moreover, the results also indicated that for those previously holding a stock, activation in the anterior insula (AI) played a key role in predicting a lower probability of choosing a stock in the next trial, while for bondholders activation in the nucleus accumbens (NAcc) was dominant, predicting a higher probability of picking a stock in the next trial. These two brain regions already had been documented as accounting for risk aversion or the anticipation of pain (negative arousal), and the anticipation of monetary gains (positive arousal), respectively. Given confirmation that the human brain is hard-coded to produce a behavior that eventually results in mean-reverting prices, it is not surprising that, 30 years after its discovery, mean-reversion remains a significant feature of capital markets. Investors could exploit this relationship by searching for signals that lead to the activation of these brain regions and then linking these patterns directly to investment decisions.

**Lobal Domination**

Most brain activity related to financial decision making takes place in the frontal lobe.

In another study, Kuhnen, who has degrees in both neuroscience and finance, and Knutson, whose main field of research is the neural basis for emotions, show that emotional states influence decision making significantly through a similar channel. Exogenous positive or negative arousals are followed by increased neural activity in the NAcc and AI regions, leading to overly risk-seeking or risk-averse behavior, respectively. By presenting highly arousing positive pictures (such as erotica), negative pictures (such as of rotten food) and neutral pictures before each trial, the researchers measured an excessive, insufficient and average probability of selecting stocks instead of bonds. Although in real situations it wouldn’t be easy to identify such direct signals for the arousal level, the implied volatility of options and other sentiment indicators might give a clue to the general level of investors’ emotional state. This pattern supports the well-documented phenomenon of bull and bear markets happening during low- and high-volatility regimes, and stochastic volatility models presenting negative correlation between volatility and residuals.

Neuroimaging can aid the grouping of assets by tracing back to the source of key characteristics in the human brain. Using event-related fMRI, Knutson worked with University of Melbourne neuroscientist Peter Bossaerts to analyze the part of the brain involved in pricing and preference tasks. By communicating the price of a product but delaying showing the product itself, Knutson and Bossaerts were able to separate the brain functions active during preference making, price comparison and the subsequent choice of whether to buy the product. Revealing that product preference activated the NAcc and price perception affected the medial prefrontal cortex (MPFC), the study proved that the two elements of purchasing decisions are controlled by distinct neural circuits. This finding in 2007 highlights the importance of, and provides an explanation for, a behavioral study on preference reversal that was published by Decision Research psychologists Sarah Lichtenstein and Paul Slovic more than 35 years before. The earlier results showed that when facing a choice between winning a low amount with high probability and winning a high amount with low probability, most subjects preferred the former. However, when they had to make bids on these two games, the latter was priced higher in most cases, indicating that pricing and preference yield inconsistencies in decision making. As mentioned above, the relevance of these results to algorithmic trading could lie in clustering: Assets for which demand is driven by preference (for example, mutual funds, where investors choose from prepackaged portfolios) should have entirely different dynamics from assets purely driven by a continuous bidding process (individual stocks or options).

The results of neuroeconomic research can provide an explanation for region- or culture-specific patterns in stock trading. As discussed above, risk tolerance and impatience are hard-coded
in our brains. But some of these attributes are different for distinct cultures at the neural level. In fMRI experiments Stanford University psychologists Bokyung Kim and Samuel McClure and Korea University psychologist Young Shin Sung analyzed the brain functions of Western (American) and Eastern (Korean) cohorts in a simple delay-preference game (choosing between X today or X+Y in one week). In line with previous results, the authors found that activation in the ventral striatum (VStr) region significantly changed before decisions involving time discounting. However, their findings also discovered an important difference between Western and Eastern brain functions: Although the VStr was activated in both groups, the brain region showed greater activity for immediate rewards in Western subjects, while in the Eastern group greater activity was measured for delayed rewards — providing an explanation for the well-documented higher discount rate of Western investors. These results highlight the importance of regional differences among stock markets and in this particular case the yield curve differences of fixed-income assets: Higher discount rates mean higher bond yields in different cultures and may offer a basis for carry trade strategies.

Because of the increasing time and space resolution of brain-imaging techniques, growing access to machines in neuroscience and a surge in the number of researchers devoted to neuroeconomics, a wide variety of studies on how humans are hard-wired to make financial decisions is being published every year. Pairing these results with alternative data that can be linked directly to these brain functions may yield a significant contribution to portfolio management.

**The Era of Big Data**

Today it is common knowledge that we live in an era of Big Data. Those who fail to use this vast quantity of information to its full potential value will face serious disadvantages. The competition related to processing Big Data is particularly strong in the financial industry, where investors cautiously look for profitable opportunities arising from unexplored anomalies in the capital markets. The data being collected around the world reflects the demand for and the supply of alternative sources of information: The volume is expected to grow from 7.9 zettabytes in 2015 to 180 zettabytes by 2025, according to Framingham, Massachusetts–based research firm IDC. Nevertheless, accessing this trove of data has both advantages and disadvantages.

On the one hand, the potential value can be extremely high and can yield a significant performance edge over competitors. On the other hand, if the data is not carefully cleaned and filtered, a phenomenon called overfitting can result, in which processing and machine learning techniques can lead to seemingly perfect pattern recognition that in fact has little predictive value.

One straightforward way to avoid false patterns is to filter out input variables that are not relevant to determining the outcome. Selecting these factors, however, might prove to be a highly difficult task, even for experienced data scientists. Instead of looking purely at the statistics of the sampled data, researchers might also use direct methods that explain the processes underlying the outcome. When searching for patterns in financial data, neuroeconomics may come in handy because of its fundamental nature: Given that asset prices are driven by investors, capturing investors’ hard-wired reactions under certain circumstances would likely generate valuable information. In other words, looking for nonlinear patterns in the input variables affecting the brain functions involved in financial decision making should yield better out-of-sample performance than simply scanning a much larger sample space in the hope of finding a robust pattern.

With an ever-growing quantity of data and methods that are expected to improve exponentially, neuroeconomics could shape the future of quantitative finance. By capturing and formalizing human behavior in directly measurable ways, neuroeconomics can transform the black box of investors’ decision making into a highly complex machine based on well-defined rules. Quants then can apply patterns that are directly connected to the elements of this decision-making process to try to predict market participants’ actions and thus asset prices. Although it may seem surprising to regard human thinking as an analytically tractable model, it is not outlandish. After all, as John von Neumann famously put it, “When we talk mathematics, we may be discussing a secondary language built on the primary language of the nervous system.”

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References


