



THE ECONOMY AND NEUROSCIENCE

# Investment *and* Impact of Research

While biomedical research advances science and improves health for millions around the globe, it also has a powerful economic impact. Although much research in this area predates the recent economic downturn, the data indicate the long-term value of science as an economic engine.

## The U.S. and Global Biomedical Investments

In the United States, biomedical research investment has been a story of upward growth, but subject to

wide swings. The years 1998 to 2003 were an economic boom, in large part because Congress doubled the budget of the National Institutes of Health (NIH), the hub of America's federal biomedical research enterprise. However, following that strong investment, the NIH budget crested in 2003 and began to fall in real dollars, creating an 11 percent drop in purchasing power. Many scientists were severely underfunded or not funded at all. In 2000, scientists who tried to renew a previously

funded grant succeeded 53 percent of the time on first submission. By 2008, that success rate dropped to less than 24 percent. Given estimates that each NIH grant funds approximately six to seven jobs, the implications extended beyond the laboratory into local communities.

The American Recovery and Reinvestment Act was an historic affirmation of the role science plays in the economy and provided a crucial boost at a crucial time. Passed by Congress in early 2009, it

is specifically focused on investing in science to create or preserve jobs over a two-year timeframe, while also funding excellent, peer-reviewed science. NIH will receive close to \$10.4 billion and the National Science Foundation (NSF) will receive \$3 billion. This support will be crucial to universities, research institutes, their faculty, and staff — and to the communities in which they work.

Moreover, as part of his pledge to “restore science to its rightful place,” President Obama has indicated that he wants the United States to increase its research and development budget to 3 percent of gross domestic product (GDP), an increase of approximately \$46 billion annually from the current investment of 2.7 percent. A modest approved increase in the FY09 NIH and NSF federal budgets begins to make welcome progress toward that goal, but bold and visionary increases in FY10 and beyond will be necessary to meet it.

Worldwide, a commitment to basic and clinical science has enabled many countries from Japan and Singapore to Germany and the United Kingdom to become world leaders in medical and scientific discovery. For instance, Japan dedicates 3.61 percent of GDP for its science budget, putting it near the top worldwide with South Korea, while Germany invests 2.53 percent. As in the United States, many advocates in these regions, including in the European Union, are calling for additional increases as part of efforts to combat difficult economic times.

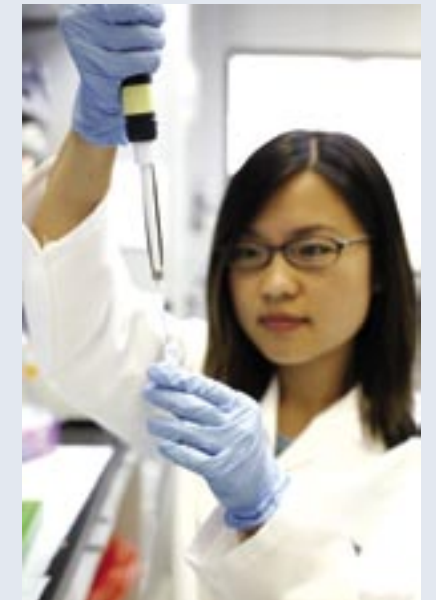
## U.S. Job Creation and Biomedical Research

The creation of new jobs is especially important during a recession, and biomedical research supports high-wage jobs. In 2007, NIH grants and contracts created and supported more than 350,000 jobs, generating wages in excess of \$18 billion. The average annual salary was \$52,000, nearly 25 percent higher than the national average. Every dollar of NIH funding generated more than twice as much in state economic output: an overall investment of \$22.84 billion from NIH generated a total of \$50.53 billion in new state business, taking the form of increased output of goods and services. Between 80 and 90 percent of NIH's annual budget funds research in local communities, including universities, hospitals, and research institutes in every state.

## Private Sector Investment, Public Benefit

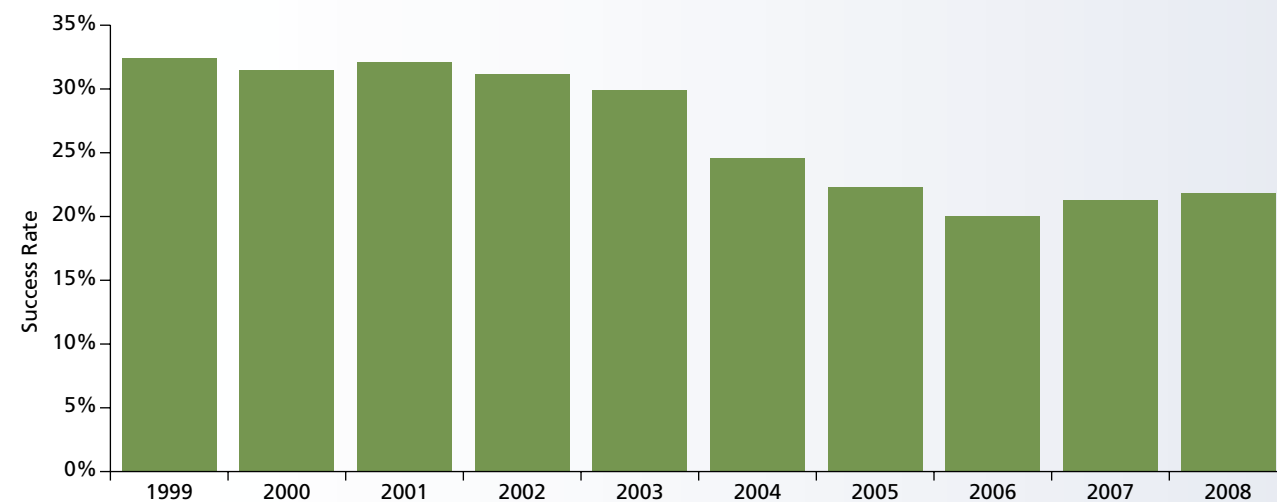
Federal investment also can help spark public-private partnerships, support small businesses, and yield state-wide benefits. One example is the Small Business Innovation Research program at NIH, which funds small companies interested in biomedical or behavioral research. In 2005, NIH expended approximately \$562 million. Beyond government funding, a neurotechnology industry group estimates that venture capital investments in the field for 2005 totaled about \$1.5 billion. Bioscience venture capital investments more broadly have been tallied at more than \$11.6 billion nationwide in 2007.

The public-private funding can pay off, which is why many states



compete aggressively to secure biotechnology investments and attract companies. A key example is New Jersey. A 2007 report found the state's biotechnology industry impact to be in excess of \$1.7 billion with more than \$80 million in generated tax revenue. Other leading states include California, New York, Minnesota, Texas, Tennessee, North Carolina, and Pennsylvania. Other midwestern states, such as Nebraska, Utah, and Missouri, are also growing their biotech sectors and are overall among the most competitive in the United States. Smaller states, such as Maryland, Delaware, New Hampshire, and Connecticut, lead the way in medical devices and research.

Clearly, the interplay of public and private investment can keep nations at the forefront of scientific discovery and better physical and mental health. Policymakers increasingly recognize that encouraging job and industry growth also can contribute to greater economic health.



**Above:** The application success rate for National Institutes of Health research project grants declined from about 32 to 21 percent over the past decade. **Opposite page:** Public and private sector neuroscience investments create discoveries and jobs that ultimately result in new therapies and diagnostic tools.



THE ECONOMY AND NEUROSCIENCE

# Neuroeconomics: Money and the Brain

Whether to hold or sell a stock, or rent or buy a house, we all face important economic decisions. These decisions can be stressful, rewarding, or both. Researchers in a new field called neuroeconomics are studying how the brain evaluates economic information and weighs financial risks and social exchanges.

Much of neuroeconomics is based on decision theory and game theory, mathematical ways to study risks and rewards in the presence or absence of social pressures. In the 1950s, researchers developed a classic social predicament called the Prisoner's Dilemma. In this game, two people play criminals who are interrogated independently about a crime they committed together. If the partners remain silent (cooperate), they both benefit, but if one chooses to testify against the other (defect), harsh punishment may result. Each participant tries to minimize his own punishment without knowing his partner's intentions. Should he risk trusting his partner, or should he betray him?

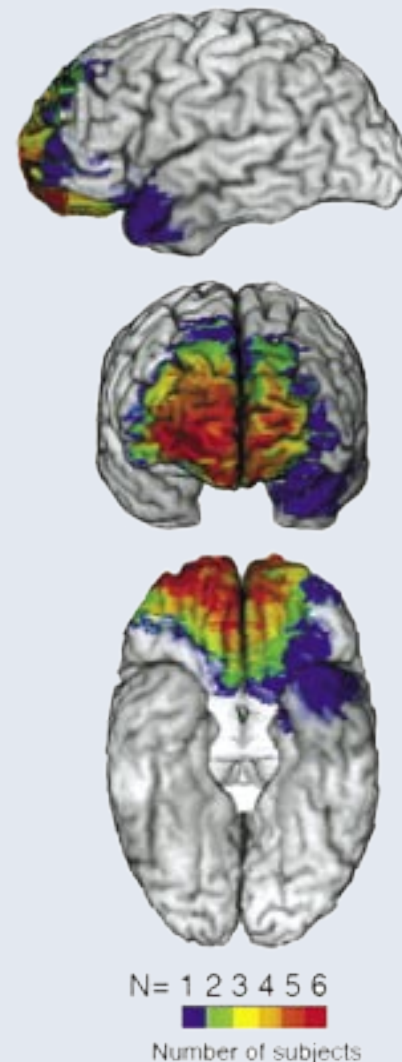
Many neuroeconomics researchers study games that create different kinds of personal and social rewards. In a variation on the classic Prisoner's Dilemma game, each player has an item of

worth, but each values the other's item more than his own. If a player chooses to cooperate, he gives his item to the other player; if he defects, he keeps it. Both players benefit from exchanging goods. However, if one player cooperates, and the other defects, the first ends up empty-handed and the second takes all.

## Brain Imaging and Economic Games

Brain imaging studies show that people find cooperating socially rewarding. When both players cooperate, a brain region involved in anticipating reward called the striatum becomes active. However, if a player faces off against a computer instead of a human, mutual cooperation does not increase striatal activity, suggesting that the social interaction of the economic exchange is rewarding.

Punishing unfair opponents and donating money to charity also are rewarding, according to imaging research, suggesting that people may have an innate, biological sense of equity. In repeated rounds of the game, if players are given



**Above:** Damage to the frontal cortex affects the ability to make good financial decisions. Each color indicates the injured region in each of six study participants.

the option of penalizing their opponents for repeatedly defecting, an economic punishment activates the striatum, but a physical punishment does not. In addition, the more a participant chooses to donate to a charity, the greater the activation in his striatum.

Researchers determined other brain regions involved in gauging financial fairness by studying people with injuries or lesions. In

## Hormones and Trust

A hormone also may increase trust in financial exchanges. In a trust game, an investor decides how much money to give to an investment trustee. The trustee automatically triples the investment, but can decide how much money to return to the investor. Investors who took a sniff of oxytocin, a hormone involved in lactation and birth, invested more

## Risks and Sure Bets

What about financial decisions that do not involve social relationships? Like people who only play the lottery when the jackpot breaks records, researchers found that animals choose risky options over smaller sure bets when they cannot predict the likelihood of a reward. Furthermore, both human and primate research shows that the

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the ultimatum game, one player makes an offer to another player who can accept or reject it. Most people accept fair offers and reject unfair ones. However, people who have lesions in the ventromedial prefrontal cortex, a brain region important in cognitive control, reject more offers than others. In contrast, when researchers temporarily inactivated the right dorsolateral prefrontal cortex in healthy people, they found that affected study participants accepted more unfair offers.

money than did other investors. However, oxytocin did not affect investor decisions when a random mechanism, rather than a person, determined their return.

Imaging research suggests that oxytocin reduces people's fear of betrayal. After learning that their trust had been violated in repeated games, investors decreased their investments, and their brains showed increased activity in regions involved in fear (amygdala and midbrain) and arousal (insula and postcentral gyrus). However, those who sniffed the oxytocin spray did not change their investments and did not show brain activity changes.

striatum becomes more active as the size of an expected reward increases. And in humans, insula activity increases with the perceived risk of a financial decision.

In today's financial climate, many are experiencing challenges to their comfort level with risk and reward and social and financial responsibilities to others. By helping researchers understand these complex human behaviors, neuroeconomics is helping to bridge biological and social sciences, offering a view into behaviors maintained across evolution as well as those that are uniquely human.