argument. I wonder whether Bernstein has ever looked at the large errors of macroeconomic forecasts, and asked himself whether, given the current state of knowledge, an effective countercyclical policy is feasible.

I do not mean to give the impression that someone writing a wide-ranging book for a general audience should be held captive to the opinions of experts in narrow fields. Experts have their own biases and constricted visions and may well be wrong. But their conclusions have to be engaged in serious debate, and not dismissed as those of "mouthpieces.Ẅhere does that leave us? The first three quarters of the book can be read with profit by economists, as well as by the general public. In writing it Bernstein has performed a useful service. The last quarter is more suited to a different readership: those on the left who want to read stirring, but unsupported, affirmations of their beliefs. And it should also be read—but in all probability will not be—by those on the right who also make stirring, but unsupported affirmations, and could do with a mirror that shows them how their posturing is likely to look to others. But those who prefer scholarly and scientific analysis should look elsewhere.

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**Paul W. Glimcher, Decisions, Uncertainty, and the Brain, MIT Press, Cambridge, MA, London, UK, 2003, ISBN 0-262-07244-0, 375 + xx pp., index, $37.95.**

Late in my first year of doctoral studies at Minnesota, I boldly (i.e., naively) strode into an esteemed professor's office with the intention of laying out a new model of bounded-rationality. The professor would have none of it, I was quickly dismissed and encouraged to focus on more productive areas. As I slowly exited he remarked to me, "Without rational expectations, our profession would be lost." Well, my dissertation ended up dealing with bounded-rationality anyway, and although I did not work with that particular professor, his offhand-comment has stayed with me. His point is clear: rational expectations is among a fairly small number of widely accepted assumptions we economists use to discipline our choice theories. And behavioral economics has not yet provided us with a widely accepted alternative. Sure, there have been lots of great ideas and even some progress. For example, I did not learn anything about hyperbolic discounting in grad school, while it is now taught routinely. But the sea change in economic modeling that many of us think is required still seems far off. Bringing it closer requires restrictions. We need empirically verifiable, context-independent and (with luck) simple restrictions that can be incorporated into our structural models of micro and macro behavior. I believe that neuroeconomics, which is an increasingly widely practiced synthesis of neuroscience, biology, psychology,

and economics, is likely to play a role in identifying these restrictions. And I think that most economists who read Paul Glimcher's book, the first book to appear on neuroeconomics, will end up agreeing with me.

Glimcher is a neuroscientist, and director of the Laboratory for Sensory-Oculomotor Research, at New York University. Much of his research has involved measuring the activity of single-neurons in primate brains, while they perform various experimental tasks. It is perhaps not surprising then that, to Glimcher, an important part of neuroeconomics involves using an economist's toolbox "to provide an overarching theory of how the [neural] computations that underlie behavior are organized and produced by the brain" (p. 322). The hope is that a model so constructed will provide new results, or restrictions, on the link between brain, mind, and behavior.

A history of scientific thought on the relationship between behavior, mind, and brain forms the first half of Glimcher's book. This history is well done and interesting, beginning in 1738 with Vaucanson's Duck and proceeding through many of the 20th century's major players: Kurt Gödel, Alan Turing, Steven J. Gould, and especially David Marr all make appearances in the story. For Glimcher, however, the history begins and ends with Descartes. He argues that Descartes' ideas led to a "reflex" based theory of brain and behavior, and that "reflexology still forms the core of how [neurobiologists] think about the relationship between behavior, brain and mind (p. 112)."

Glimcher argues that reflex-based modeling has been tremendously useful, but has become something of a victim of its own success. He suggests that "we [neurobiologists] intentionally circumscribe both the behaviors we study and the models we build to allow us to employ [reflex-based] approaches in our study of the brain" (p. 113). For those of us interested in cross-disciplinary research this is great news. Now, we know that neurobiologists and economists have something important in common: we all would rather find questions that we can answer with the tools we know.

Glimcher goes further. He argues that even absent this 'first tool then question' issue, a reflex-based approach could not likely succeed in shedding light on the deeper cognitive architecture tied to observed behaviors, which is after all the point. On this he quotes (repeatedly) David Marr: "an algorithm is likely to be understood more readily by understanding the nature of the problem being solved than by examining the mechanism (and the hardware) in which it is embodied." An economist will understand Marr to be making something like a Lucas-critique: you have to get inside the black-box if you hope to make progress. Interestingly, while the Lucas-critique revolutionized economic modeling, Glimcher suggests that, although neurobiologists recognize the value of the "Marr" approach, and even deny the importance of the reflex-paradigm in their own work, it is in fact pervasive. The first half of the book is filled with examples designed to convince the reader on this, and I found the arguments to be convincing.

In the book's second half, which is titled "Neuroeconomics," Glimcher introduces and defends his alternative to the reflex model. One important feature of reflexology is that it is deterministic: for every sensory input there is a deterministic sensory output. Glimcher argues at length, and using his own lab's research results, that this is not likely the case. Glimcher believes that some behaviors, from neurons down, are "irreducibly uncertain," by which he means that even perfect knowledge of the state of the universe would not enable one to predict with certainty the neural output associated with some sensory inputs.

Glimcher does an excellent job in describing to the reader how he came to these views, and my guess is that most readers, and particularly laboratory scientists, will find his discussion very engaging. After providing the necessary background, Glimcher details early experimental research he conducted with Michael Platt. He reports that doing those experiments was, ex-post, a "silly idea," but then goes on to show how that early work led him and Platt to the path-breaking research they eventually published in *Nature* (Platt and Glimcher, 1999). To my knowledge, their findings were the first to provide evidence that certain primate neurons might encode both probability and valuation. That is, they found evidence suggesting that some neurons are specialized to perform expected utility computations. Wow!

So at this point all those who have been pooh-poohing the neuro agenda are going to start feeling a bit nervous that they might end up way wrong on something way important. But lets be careful here. If there is in fact a utility function in the brain, what goal is attained through its maximization? Moreover, if the utility function is a manifestation of neural computations, and because these computations would likely remain stable over at least short periods of time, does not this put us back into a world of deterministic (but potentially complex) reflexology? Glimcher provides excellent treatments of both of these issues.

The main points Glimcher wants readers to take include: (i) the fundamental goal of behavior, and therefore, neural computation, is evolutionary fitness and (ii) deterministic behavior, no matter how complicated, will not likely succeed evolutionarily. A predator, for example, would likely eventually evolve to exploit and defeat prey that behaved in a perfectly predictable manner. In the same way, it seems likely that a creature that develops neural structures to generate irreducibly uncertain behaviors would have an evolutionary advantage. Glimcher's view is that evolutionary pressures lead successful creatures to play a mixed-strategy equilibrium, and that this mixing requires a supporting neural architecture.

This is where Glimcher sees economics as hugely valuable. Although behavior might be irreducibly uncertain, he nevertheless believes that, at least as a first pass, we can assume the set of behaviors that might possibly be generated from a given sensory input can be determined, and that the probability of each behavior in that set can in principle be specified. This allows him to turn to an economist's toolbox, particularly game theory, to model irreducible uncertainty. He spends a chapter describing Von Neumann and Morgenstern expected utility, Nash equilibrium, and how these concepts have been previously applied in biology, particularly the Hawk-Dove game.

Glimcher offers us a clear alternative to Descartes' dualism, which posits that simple behaviors are well modeled as reflexes, and complex unpredictable behaviors best viewed as the product of the soul. Instead, Glimcher advocates an explicitly indeterminate monism. The final chapter of the book expounds on the implications of his monism. He speculates that, for example, "free will may simply be the name we give to the probabilistic behaviors that are mixed strategy solutions" (p. 342). Although some will be disappointed that intellectual 'creativity' is not directly addressed, Glimcher does discuss links between his indeterminate monism and other important big picture ideas, including consciousness.

At the end of the day, the book is all about the big picture of neuroeconomic research. What questions should neuroeconomists ask? What methodological framework is appropriate for trying to answer these questions? Although the tools that Glimcher thinks will be valuable are discussed, he is clear that the entire program is in its infancy, and that his prior

is that most of what we think is right now, will probably end up wrong. There are some awfully intriguing early results out there; we just have to figure out what it all means.

There is no doubt that this is an important book. There are a few sections that some economists will be able to pass through quickly (e.g., the short introduction to game theory), but most of the book should be read carefully, and sequentially. Glimcher has cleverly intertwined persuasive argumentation with historical narrative and interesting anecdotes. Consequently, a quick and casual perusal of the book will not reveal its full import.

So can Glimcher's brand of neuroeconomics help us to discipline our economic approaches to seemingly sub-optimal decision-making? I suspect Glimcher would argue that this question is misguided. After all, any decision arises from neural circuitry that has been designed to achieve an overarching evolutionary goal; the point is not to understand certain classes of decisions, but rather to understand better the unified cognitive architecture that underlies decision-making. From an economist's point of view though, the question is meaningful, and I am optimistic that its answer is "yes": understanding the internal order of the brain will help to inform economic theories of individual differences, individual decision-making, social exchange, and markets. There are increasing numbers of economists who share my optimism, (see, e.g., Smith, 2003; McCabe, 2002; Camerer, 2003).

Is there really a utility function in the brain? Will we be able to see the way it assigns relative values to alternatives, and the way those values are connected to behavior? At this point, the amazing thing is that the answer is: maybe so! And, if so, then Glimcher's provocative book is at the forefront of what might be our next major scientific revolution. Better yet, I will be able to tell my professor from grad school that, as it turns out, we are not so lost after all.

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