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Economics and Epicycles

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Abstract

I aver that standard economics as a model of human behavior is as incorrect in 2017 (after Thaler) as geocentrism was as a model of celestial behavior in 1617 (after Galileo). Behavioral economic studies that have exposed the paradoxes and anomalies in standard economics are akin to epicycles on geocentrism. Just as no amount of epicycles could salvage geocentrism as a model of celestial behavior because it was fundamentally incorrect, no amount of behavioral economic adjustments could salvage standard economics as a model of human behavior because it is fundamentally incorrect. Many of the cognitive biases exhibited by humans are shared by other species, so not only are human actors Humans (as opposed to Econs), but nonhuman animals as phylogenetically distant from humans as ants and locusts are also Humans. Evolutionary biology as a model of human behavior can explain many of the hitherto unexplained cognitive biases and provide a unifying model of human behavior currently lacking in behavioral economics.

Keywords

Misbehaving, Nudge, Star Wars

> The Darwinian framework is the only scientific framework available for trying to understand why humans and other animals are motivated to behave as they do.
>
> —Robert H. Frank (2011, p. 24)

Behavioral economics is all the rage, as most clearly attested by the Nobel Memorial Prize in Economic Sciences awarded to Daniel Kahneman in 2002 and to Richard H. Thaler in 2017. For the past 4 decades, Amos Tversky, Kahneman, Thaler, and other behavioral economists have conducted numerous experiments and studies to demonstrate that humans systematically deviate from rational behavior predicted by standard economics, thereby exposing the flaws and anomalies in the theory of rational choice in standard economics (Kahneman, 2011; Thaler, 1992).

At the same time, behavioral economics has its own problems. Despite its tremendous empirical successes, behavioral economics has no theory. Standard economics at least has mathematically elegant and precise (if incorrect) theories. Although behavioral economics has shown that many of the standard economic theories are wrong, it does not have its own theories with which to replace them. Behavioral economics remains a collection of empirical findings without a general theory to explain them; it demonstrates *what* humans do under certain circumstances (in contradiction to predictions from the mathematically elegant and precise theory of standard economics), but it cannot explain *why* (Gal, 2018). Yet why, not what, is the most important question in science (Salmon, 1978); theory, not data, is the most important part of science (Weinberg, 1992).

To be fair, behavioral economists do not see a need for a new theory. As Thaler (2015) writes,

> The good news is that we do not need to throw away everything we know about how economies and markets work. Theories based on the assumption that everyone is an Econ [rational actor] should not be discarded. They remain useful as starting points for more realistic models. (p. 7)

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As excellent as Thaler's 2015 book *Misbehaving: The Making of Behavioral Economics* is as an introduction to and comprehensive survey of behavioral economics, I believe Thaler is wrong on this singular point. I believe that "theories based on the assumption that everyone is an Econ" should be discarded.

In this article, I argue that standard economics as a model of human behavior is as incorrect in 2017 (after Thaler's Nobel prize) as geocentrism was as a model of celestial behavior in 1617 (after Galileo first observed the moons of Jupiter with his telescope). Just as no amount of epicycles could salvage geocentrism, no amount of behavioral economic modifications can salvage standard economics. Just as geocentrism as a model of celestial behavior had to be abandoned completely because it was fundamentally incorrect, standard economics as a model of human behavior has to be similarly abandoned because it is fundamentally incorrect. "Theories based on the assumption that everyone is an Econ" are no more useful starting points for the true model of human behavior than geocentrism is as a starting point for the true model of celestial behavior.

To my knowledge, Cosmides and Tooby (1994) and Bonacich (2000) were among the first to suggest that evolutionary biology replace standard economics as a model of rational human behavior. Hirshleifer (1977) long argued for the integration of economics and biology; however, he believed that economics formed the theoretical foundation of biology, not the other way around. Such a suggestion violates the important scientific principle of reductionism. All good science is reductionist (Ridley, 1999, pp. 231–242; Weinberg, 1992, pp. 51–64), and fields that study smaller units of analysis are always more fundamental than fields that study larger units of analysis. The Nobel laureate Steven Weinberg puts it best: "The reason we give the impression that we think that elementary particle physics is more fundamental than other branches of physics is because it is" (Weinberg, 1992, p. 55). Elementary particle physics is more fundamental than other branches of physics because it studies smaller matter (in fact, the smallest matter known to science, elementary particles and strings) than other branches of physics do. Apart from the undeniable fact that humans and all species in nature are evolved animals subject to the laws of evolution, evolutionary biology must form the basis of economics (and all social sciences) because it is more fundamental; genes and cells are smaller than individuals, firms, and economies (Daly & Wilson, 1999; Kanazawa, 2004c; van den Berghe, 1990).

Others have previously called for the introduction of evolutionary biology as the theoretical foundation for rational-choice models in economics. Lo's adaptive markets hypothesis (Lo, 2004, 2005) introduces some biological concepts, such as species and natural selection, to revise and improve the efficient markets hypothesis. However, Lo's view places too much emphasis on individual learning via trial and error and deliberate decision making and not enough emphasis on evolutionarily selected and genetically encoded behavior to be truly evolutionary biological. Gigerenzer's notion of ecological rationality (Gigerenzer et al., 1999) highlights the fact that sometimes cognitive shortcuts, which he calls "simple heuristics," produce outcomes superior to those of deliberate rational calculations based on all available information. Unlike Lo's adaptive markets hypothesis, Gigerenzer's work (especially Gigerenzer, 2007) properly recognizes the importance of unconscious and automatic decisions and actions. However, Gigerenzer does not explain the exact evolutionary logic and selection process behind the simple heuristics he enumerates, how the particular heuristics he identifies were evolutionarily selected, and what adaptive problems they solved in the ancestral environment.

McDermott et al. (2008) provide the evolutionary biological foundations of prospect theory, one of the most prominent theories in behavioral economics, and how the human evolutionary history of hunting and gathering has selected for the well-known prospect preferences (risk aversion in gains, risk seeking in losses). I seek to continue their work and provide evolutionary biological explanations for a much larger number of behavioral economic empirical successes.

Behavioral Economics as Epicycles

Our ancestors from time immemorial assumed that the earth was the center of the universe, and all celestial bodies—the sun, the moon, and the planets—revolved around the earth. Geocentrism as a model of celestial behavior was never questioned because all evidence available to the senses was consistent with it. The earth certainly did not feel as if it was moving, and, to the casual observer, all the celestial bodies moved across the sky every day and night steadily like clockwork. Geocentrism was a perfectly reasonable model of celestial behavior given the sensory evidence available to observers for tens of thousands of years (Gal & Rucker, 2018, pp. 511–512).

As the first generations of natural philosophers began making and recording systematic and precise observations of planetary movements, however, they began to notice that there were some inconsistencies between the geocentric model and the precise movements of the celestial bodies. The planets did not seem to move at a constant speed, and they sometimes even seemed to reverse course. To account for the empirical anomalies that they observed, recorded, and accumulated, incipient astronomers proposed the concept of

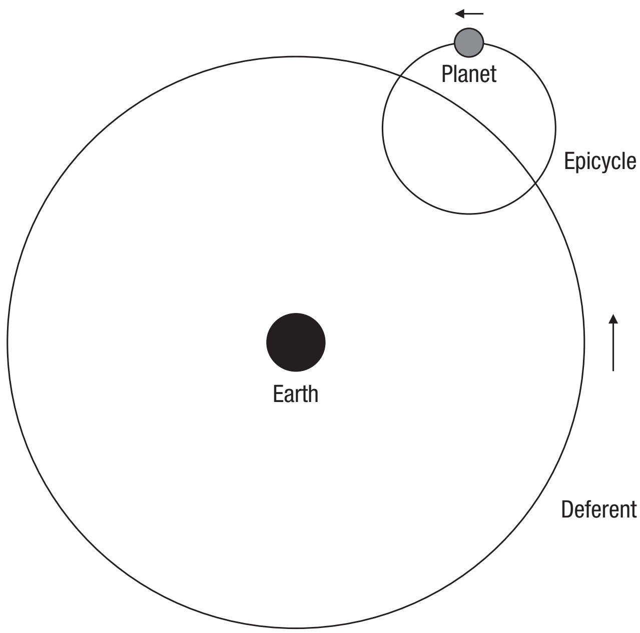

Fig. 1. Illustration of an epicycle.

epicycles. They speculated that celestial bodies revolved around the earth in a large circular orbit (known as *deferent*) while at the same time circling the course of the deferent in a smaller circle called an epicycle (Fig. 1). Epicycles could explain why planets did not seem to move at a constant speed from the perspective of the observers on the earth and why they sometimes seemed to reverse course.

Invoking the notion of the epicycle salvaged the geocentric model by making all known observations consistent with it, *until* astronomers made even more precise and systematic observations that could not be accounted for even by the epicycles. In such instances, astronomers sometimes proposed *epicycles on epicycles* (Fig. 2) to adjust the model even further to be consistent with the observations (Gallavotti, 2001, pp. 131–134; Moritz, 1995, pp. 257–259). The geocentric model ultimately included a very large number of epicycles and epicycles on epicycles to account for all of the empirical anomalies from the perspective of geocentrism, until Galileo invented a telescope and observed that the Jupiter appeared to have its own moons that revolved around it, making the assumption untenable that all celestial bodies revolved around the earth. Geocentrism was eventually abandoned in preference for Copernican heliocentrism as well as Keplerian elliptical orbits.

There is a clear parallel between geocentrism and standard economics, with behavioral economics as epicycles. For example, standard economics holds that humans are subjective expected-utility maximizers and treat gains and losses equivalently. Their risk attitudes—whether they are risk averse or risk seeking—do not depend on whether they are contemplating gains or losses. Losing \$100 is mathematically identical to gaining –\$100. This is the deferent.

Prospect theory (Kahneman & Tversky, 1979) was one of the earliest empirical successes of behavioral economics, and numerous experiments conducted by Kahneman, Tversky, and their associates demonstrated that human actors do not treat gains and losses equivalently. In particular, humans tend to be risk averse in gains and risk seeking in losses. Most people prefer a gamble in which there is a 50% chance of losing \$200 and a 50% chance of losing nothing to a certainty of losing \$100. The same people would prefer a certainty of winning \$100 to a gamble in which there is a 50% chance of winning \$200 and a 50% chance of winning nothing. So, contrary to standard economics, gains and losses are not equivalent, and humans are risk seeking in losses and risk averse in gains. This is the epicycle.

So humans are risk seeking in losses and risk averse in gains, *except* when they are playing with house money (Thaler & Johnson, 1990). When gamblers in casinos win big early in the evening, they typically treat their winnings not as their own money but as house

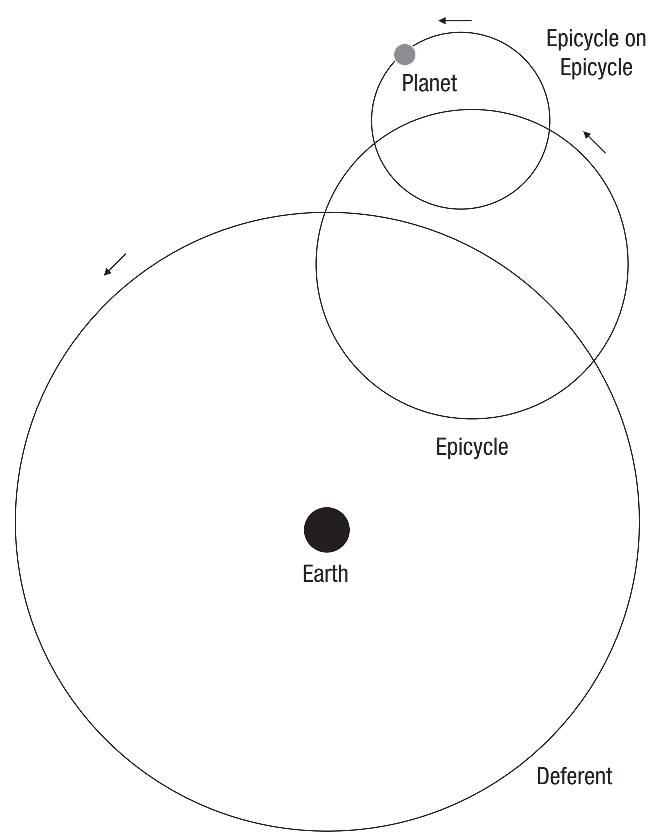

Fig. 2. Illustration of epicycle on epicycle.

money (belonging to the casinos). When they then gamble with their earlier winnings, they tend to be risk seeking in gains and risk averse in losses, exactly the opposite of how they behave with their own money. This is the epicycle on epicycle. Human actors are rational (deferent), *except* that they are risk seeking in losses and risk averse in gains (epicycle)—*except* when they are gambling with house money, in which case they are risk seeking in gains and risk averse in losses (epicycle on epicycle). All of the paradoxes and anomalies that behavioral economists have documented in their experiments and studies over the past few decades may be seen as epicycles and epicycles on epicycles on the deferent of standard economics. With the help of these epicycles and epicycles on epicycles, the underlying model of human behavior posited by standard economics is salvaged—except it is not.

What Is Standard Economics?

What exactly do behavior economists mean by "standard economics" when they critique it with their experimental data? The foundations of standard economics are cost–benefit analysis and self-interested behavior. The crucial point is that cost–benefit analysis and self-interested behavior are theoretically vacuous and useless.

Economic theory falls into two ideal types: thin and thick (Ferejohn, 1991; Hechter, 1996). Thin models merely posit that human behavior is a consequence of cost–benefit analysis and that human behavior is self-interested. It proposes that human actors do whatever they can within their constraints to achieve what they want to achieve but does not specify what it is that they want to achieve.

Consequently, thin models are tautological, true by definition, and therefore unfalsifiable. If Actor A who faces a budgetary constraint of $10 purchases apples instead of oranges, and Actor B under the identical budgetary constraint purchases oranges instead of apples, both outcomes support the thin model of rational economic behavior by positing, ex post, that Actor A prefers apples to oranges whereas Actor B prefers oranges to apples. In fact, *all choices* support the thin model of rational economic action by positing appropriate preferences ex post. Human behavior under the thin model is irrational only if the preferences are not consistent and transitive. If Actor A prefers apples to oranges, and oranges to bananas, yet prefers bananas to apples, then such a preference hierarchy is intransitive and therefore irrational.

Note that thin models of rational economic behavior cannot predict any human behavior ex ante. It cannot predict the purchase decisions of Actor A or B without knowing what their preferences are. Likewise, the law of supply and demand, universally regarded as the most solid principle in economics, cannot predict actual trading behavior unless one specifies what buyers and sellers value as commodities. One person's trash is another person's treasure. In this sense, thin models of rational economic behavior are like democracy as a political institution. Democracy is a mechanism of aggregating voter preferences in an election but cannot by itself predict who will win an election. It depends on what the voters prefer. The same institution of democracy led to the election of President Mohamed Morsi of the Muslim Brotherhood in Egypt in 2012 and of President Donald J. Trump of the Republican Party in the United States in 2016 because voters in these two electorates had radically different preferences. Neither electoral outcome—in fact, no electoral outcome whatsoever—can ever be predicted simply by knowing that a country is democratic. Likewise, no human behavior can ever be predicted or explained under the thin model by knowing that human behavior is rational and preferences are consistent and transitive.

To predict and explain human behavior, one needs to "thicken" economic models of human behavior by supplying actors' preferences and values ex ante (Hechter, 1992, 1994). Only thick models that make actual empirical predictions can be tested and falsified. Yet economists have steadfastly refused to do so by arguing that economic models cannot explain individual preferences and values (Stigler & Becker, 1977). Economists choose not to endogenize idiosyncratic individual preferences and values; they instead posit wealth maximization as a universal value shared by all human actors because wealth is fungible. No matter what idiosyncratic values human actors may have, all are better off with more wealth than less because wealth can be used to purchase all private goods. Greater wealth would allow Actor A to purchase more apples and Actor B to purchase more oranges; thus, both Actors A and B would prefer to have more wealth.

By standard economics, I mean both the thin and the thick models of rational economic behavior, the set of assumptions in the former and empirical predictions of the latter. I contend that evolutionary biology would provide a comprehensive explanation for the origin of human preferences and values currently lacking in economics and can thus be used to thicken the model of rational human behavior by endogenizing actors' preferences and values (Kanazawa, 2001).

Maestripieri (2012) and Kenrick and Griskevicius (2013) provide premier examples of how evolutionary biology can be used to provide the explanations of human preferences and values that can be used to thicken models of evolutionarily (not economically) rational behavior; however, their models violate assumptions of thin models of rational economic behavior and are thus inconsistent with standard economics. Maestripieri (2012, pp. 109–115) emphasizes the importance of what Thaler (2015) calls "supposedly irrelevant factors," such as social contexts, in explaining human behavior, and Kenrick and colleagues (Kenrick & Griskevicius, 2013; Kenrick et al., 2010) posit multiple, mutually conflicting hierarchies of preferences rather than a unitary, consistent hierarchy mandated by standard economics.

Although Maestripieri, like Thaler, does not favor abandoning standard economics en masse, he nevertheless captures why it must be, in my mind, abandoned and replaced by evolutionary biology as a model of human behavior, in the following passage:

> Economists used to think that people always make rational choices that maximize their gains, and that they make choices in isolation from their social context without regard for the consequences of their behavior. Researchers studying animal and human social behavior from an evolutionary perspective, however, have discovered that maximizing one's fitness—like maximizing one's earnings—often depends on taking others into account. As we'll see, the integration of economic models with evolutionary theory and the findings of animal and human behavioral research can result in more sophisticated and more predictive models of human decision-making and ultimately help bridge the gap that still separates economic and biological explanations of behavior. (Maestripieri, 2012, p. 115)

Both Maestripieri (2012) and Thaler (2015) believe that standard economics needs to be modified but is ultimately salvageable. I do not share their optimism.

Game theory, one of the more successful branches of economics, works at the "thin" (mathematical)-level prediction of cost–benefit analysis in that actors choose to maximize payoffs and minimize loss. But it does not work at the "thick" (behavioral)-level prediction, such as cheap talk does not affect choice or all rational actors defect in one-shot Prisoner's Dilemma games (Sally, 1995). Game theory works, not because economics works, but because biology works. As explanatory principles, cost–benefit analysis, tit for tat, and the law of supply and demand are as much biological as economic (Axelrod & Hamilton, 1981), and, once again, biology is more fundamental than economics. Biology can exist without economics, but economics cannot exist without biology. Given that humans are but one species in nature, economics—and all of the social sciences that study humans—are properly branches of biology (Daly & Wilson, 1999; Kanazawa, 2004c; van den Berghe, 1990). In my critique of standard economics, I include game theory *only* when it is thickened by economic (wealth-maximization) preferences, not when it is thickened by biological (fitness-maximization) preferences, as in Maestripieri (2012).

Econs Are Robots, Humans Are Animals (and Animals Are Humans)

Thaler and Sunstein (2008) first introduced the distinction between Econs and Humans. Econs are the rational actors that standard economics assumes human actors to be in theory, whereas Humans are what behavioral economic experiments reveal human actors to be in reality. Econs are subjective expected-utility maximizers who compute, quickly and accurately, gains and losses likely to follow from different courses of actions by weighing expected outcomes by their subjective probabilities; they then choose the course of action that maximizes their subjective expected utility. Humans, on the other hand, often rely on cognitive shortcuts known as heuristics to avoid making all of the necessary calculations to arrive at a rational choice, and they are subject to a large number of documented errors of judgments such as the sunk-cost fallacy, endowment effects, and availability heuristics.

The problem is that Econs do not exist (Thaler, 2015, p. 348). They were invented by economists, and human actors are assumed by fiat to be Econs (Cosmides & Tooby, 1994). Apart from this assumption, however, there is no reason to believe that human actors are Econs, and all of the behavioral economic data suggest that they are not. Perhaps the best evidence that Econs do not exist is the fact, pointed out by none other than Thaler himself, that even economists, who invented Econs, are not Econs. Two illustrative examples suffice.

Thaler (2015, pp. 271–276) relates an amusing anecdote about how the faculty of the Booth School of Business at the University of Chicago, where some of the best economists in the world teach, allocated offices when they moved into a new building in 2002. Economists usually concur that open markets and auctions are the most efficient means of allocating scarce goods. Given the heterogeneity of preferences, in which some individuals value a given commodity more than others, those who value a given commodity more will be willing to pay more for it than those who value it less. Hence, allocating scarce goods on the open market, such as auctions, would be most likely to leave everyone satisfied.

Yet this is not how the economists and other faculty members at Chicago Booth decided to allocate the office spaces. They settled on a draft system, in which individuals ranked higher in the draft got to pick their offices before those ranked lower. Full professors as a group picked first, associate professors picked second, and assistant professors picked third. Among associate and assistant professors, the order of picking within the category was determined by random lotteries. Among full professors, three "bins" were created: Bin A for the "stars," Bin C for the "deadwoods," and Bin B for everyone else. One person—the deputy dean for the faculty—allocated all full professors into the three bins. Those in Bin A picked first, those in Bin B picked second, and those in Bin C picked third. Within each bin of full professors, the order of picking was determined randomly. Quite predictably, a large number of full professors were angry with the whole process, both about the bin to which they were allocated and about their random order within that bin.

These economists, arguably among the best in the world, opted not to use the open market to allocate their future offices. Further, the deputy dean specifically prohibited two features of an efficient market: Faculty members could not trade the offices they picked, and they could not buy an earlier draft pick from a colleague. Thaler (2015) stated that

> This ruling and the fact that the school decided not to simply auction off the draft picks, reveals that even at the University of Chicago Booth School of Business—where many favor an open market in babies and organs—some objects are simply too sacred to sell in the market place: faculty offices. (p. 271)

The second illustration of how even economists are not Econs concerns Harry Markowitz, one of the founders of the modern portfolio theory who won the Nobel prize in economics in 1990 for his work (Thaler & Sunstein, 2008, pp. 133–136). His portfolio theory stipulates the efficient and rational allocation of retirement funds across various investment options. Yet Markowitz himself does not follow his own theory, the very one for which he won the Nobel prize:

> I should have computed the historical co-variances of the asset classes and drawn an efficient frontier. Instead, I visualized my grief if the stock market went way up and I wasn't in it—or if it went way down and I was completely in it. My intention was to minimize my future regret. So I split my contributions 50/50 between bonds and equities. (Zweig, 2017, para. 2)

Even the best economists are not the Econs that they unquestioningly assume all human actors to be.

What the standard economic notion of Econs—rational actors—neglects is that, just like every other species in nature, humans are *evolved animals*, and there is nothing in human evolutionary history that would have made humans (or any other organism) rational in the economic sense, for the simple reason that human evolution far preceded the invention of economics and *Homo economicus*. Prior evolutionary constraints that we inherited from our nonhuman ancestors would have prevented the creation de novo of a perfectly rational mind. This is most clearly demonstrated by the fact that all of the flaws and shortcomings from which behavioral economists have discovered that the human mind suffers are shared by nonhuman species, as clearly demonstrated by superb reviews by Santos and Rosati (2015) and Magalhães and White (2016).

Studies show that ants (Czaczkes et al., 2018), locusts (Pompilio et al., 2006), banded tetras (Aw et al., 2009), pigeons (Avila-Santibañez et al., 2010; Macaskill & Hackenberg, 2012a, 2012b; Navarro & Fantino, 2005), starlings (Marsh et al., 2004; Pompilio & Kacelnik, 2005), and mice and rats (Magalhães et al., 2012; Sweis et al., 2018) all suffer from the sunk-cost fallacy; rhesus macaques and capuchin monkeys discount the future (Watzek & Brosnan, 2018); capuchins (Chen et al., 2006; Lakshminarayanan et al., 2011) and European starlings (Marsh & Kacelnik, 2002) are susceptible to the framing effects and loss aversion; rhesus monkeys share the peak-end effect (Blanchard et al., 2014); capuchins show choice-induced preference changes, otherwise known as cognitive dissonance (Egan et al., 2007, 2010); and chimpanzees (Brosnan et al., 2007), gorillas (Drayton et al., 2013), orangutans (Flemming et al., 2012), and capuchins (Lakshminarayanan et al., 2008) all exhibit the endowment effect. Thus, humans are not the only Humans; monkeys, apes, mice, rats, pigeons, starlings, banded tetras, locusts, and ants are also Humans.

It's Not a Bug, It's a Feature!

Santos and Rosati (2015, pp. 335–339) argue that cognitive biases and anomalies that primatologists have documented among monkeys and apes, and that behavioral economists had earlier documented in humans, are not irrational cognitive errors but instead evolved tendencies adapted to their own unique evolutionary history and environment. Such behavioral tendencies may be irrational from the perspective of standard economics but may nonetheless be *biologically* or *evolutionarily rational* (Marsh, 2002), *deeply rational* (Kenrick et al., 2009), or *adaptively rational* (Haselton et al., 2009).

The notion of biological or evolutionary rationality suggests that all of the paradoxes and anomalies exhibited by human actors that behavioral economists have documented over the past 4 decades may be *evolved tendencies* specifically adapted to human evolutionary history and environment. In this section, I detail how many of the paradoxes and anomalies discovered and documented by behavioral economists, assumed to be minor glitches in the functioning of the mind of the otherwise rational *Homo economicus*, are instead design features of *Homo sapiens* as an evolved animal species.

One important implication of the observation that humans are evolved animals with evolutionary (not economic) rationality is the fact that the entire human body and all of its parts (including the brain) are designed for and adapted to the conditions that obtained during their evolutionary history, known as the environment of evolutionary adaptedness (Crawford, 1993; Symons, 1990; Tooby & Cosmides, 1990). Variously known as the Savanna Principle (Kanazawa, 2004b), the evolutionary-legacy hypothesis (Burnham & Johnson, 2005, pp. 130–131), or the mismatch hypothesis (Hagen & Hammerstein, 2006, pp. 341–343), this insight from evolutionary psychology states that it is difficult (albeit *not* impossible) for the human brain to comprehend and deal with entities and situations that did not exist in the environment of evolutionary adaptedness. As it turns out, this single insight can explain many of the paradoxes and anomalies in standard economics that behavioral economists have uncovered (but have not explained) over the past 4 decades.

Risk aversion

Standard economics assumes that economic actors are mildly risk averse (Bernoulli, 1954; Pratt, 1964). Why are humans risk averse?

Risk aversion decreases the variance in fitness through the tendency of risk-averse actors to engage in bet hedging—an attempt to decrease the variance in fitness by decreasing the mean (expected) fitness, or, mathematically equivalently, an attempt to maximize geometric mean fitness rather than arithmetic mean fitness. Bet hedging is an attempt not to "put all eggs in one basket," but, rather, being prepared for various future contingencies. Risk-averse actors who engage in bet hedging therefore achieve some measure of reproductive success no matter what happens in the future.

It has been mathematically shown (Gillespie, 1974, 1977) that selective advantages of smaller fitness variance decrease with population size; selection forces for smaller fitness variance are inversely correlated with population size. This is because, in large populations, when actors with risk-seeking preference fail by leaving no offspring, their failures can be compensated for by other actors using the same risk-seeking strategy who happen to succeed in leaving large numbers of offspring because of the large fitness variance that risk-seeking strategy produces. In smaller populations, however, the failure of some risk-seeking actors is less likely to be compensated for by others using the same strategy. Hence, a risk-averse strategy is more adaptive in smaller populations (Gillespie, 1974, 1977). The question is: How small does the population have to be for smaller fitness variance, and hence risk aversion, to be evolutionarily advantageous?

Simulation studies show that risk aversion could have evolved only in a small group of fewer than 150 individuals (Hintze et al., 2015). Their results show that it does not matter how large the total human population is or what the rate of migration is between groups. As long as humans live within groups of 150 or so individuals, risk aversion is evolutionarily selected. This number—150—happens precisely to be the average size of hunter-gatherer bands during human evolutionary history, estimated from comparative data on the neocortex ratio (Dunbar, 1992, 1993). Humans therefore likely evolved in hunter-gatherer bands of roughly 150 individuals, in which risk aversion would have naturally emerged as an evolutionary adaptation. Whereas standard economics merely assumes Econs to be risk averse by fiat, without offering an explanation, evolution actually designed the human brain to be risk averse in the context and environment of human evolutionary history because it was evolutionarily rational in such context and environment. That is why most human actors are risk averse. Risk aversion is not only economically rational but also evolutionarily rational because it is perfectly adapted to the context and environment of human evolutionary history. Humans would not be risk averse today if they lived in groups much larger than 150 during their evolutionary history.

Although risk aversion is adaptive in the equivalent mean payoff gamble in small groups, Hintze et al. (2015) also note that foraging animals avoid risk when resources are plentiful and the neural circuitry that encodes risk sensitivity (such as the ventral striatum) is phylogenetically ancient. Given that, as noted above, many of the cognitive biases that humans exhibit are shared by other species as phylogenetically remote from humans as ants and locusts, it is likely that the evolutionary origins of such cognitive biases go further back in time than specific aspects of human evolutionary history, such as the group size of 150.

Mental accounting

Mental accounting was one of the first anomalies discovered by behavioral economists (Kahneman & Tversky, 1984; Thaler, 1980). Studies show that individuals, households, and organizations have separate "budgets" (sometimes physically represented by envelopes or mason jars in which people keep their money) to be spent on expenses in strictly limited purposes, such as rent, food, utilities, clothes, and entertainment, and they are often very reluctant to transfer money from one budget to another, even when unanticipated expenses call for such transfers.

For example, individuals are more reluctant to buy a ticket for a play on the weekend if they had spent $50 earlier in the week going to a basketball game (the same budget of entertainment) than they would be if they had spent $50 on a parking ticket (a different budget), although the two groups of individuals are otherwise financially comparable (Heath & Soll, 1996). When the price of gas suddenly falls, many drivers switch from regular unleaded to premium high-octane when they pump gas at gas stations attached to grocery stores because they now have more money left in their gas budget. Yet the same individuals do not purchase higher-quality groceries at the same time because groceries come from the food budget, which remains unaffected by more money left over in the gas budget (Hastings & Shapiro, 2013). Such mental accounting of different budgets is anomalous from the standard economic perspective because money is fungible. Money saved on gas can just as well be spent on groceries, yet many individuals are reluctant to do so. Fifty dollars spent on a basketball game is identical to $50 spent on a parking ticket, yet individuals do not act as if they were.

This is one of the easiest paradoxes to resolve from the perspective of evolutionary rationality, for the simple reason that fungible money did not exist during human evolutionary history. Resources were not fungible in the ancestral environment. A favor owed you by a friend could only be repaid by the same friend (or, at most, by the friend's friends or close relatives). The favor owed could not be used to ensure that one won a battle against the neighboring tribe or killed a large game animal one was hunting. A favor owed you by a friend could not even be used to repay a favor that you owed another friend. Every resource in the ancestral environment came in its own mental envelope or mason jar, and resources could not be transferred from one category to another. It is therefore not surprising that humans who evolved in such an environment maintain mental accounting. It may be a violation of economic rationality, but it is perfectly evolutionarily rational.

Availability heuristic

The availability heuristic is another cognitive bias that may violate economic rationality but is nevertheless perfectly evolutionarily rational. Suppose you are contemplating a purchase of a new truck. You read in *Consumer Reports* that a survey of 3,000 truck owners reveals that Chevy owners are happier with their trucks than Ford owners. Then, on your way out to drive to the nearest Chevy dealership, you talk to your neighbor, who has recently purchased a Ford truck. He tells you how great his Ford is and how happy he is to have purchased a Ford instead of a Chevy. After speaking to your neighbor, you are convinced by him, and you decide to buy a Ford instead of a Chevy (Markus & Zajonc, 1985, pp. 181–182).

From the perspective of standard economics, such a decision is irrational. A conclusion based on the opinions of a sample of 3,000 respondents is much more likely to be accurate than a conclusion based on the experience of a single person. In a large sample, individual idiosyncrasies and random variations cancel each other out, and the true central tendency is likely to emerge. If a survey of 3,000 truck owners concludes that more drivers are happy with Chevy than Ford, then it is likely that Chevy produces better trucks than Ford does, no matter what your neighbor might say. His opinion or experience might be highly idiosyncratic or a fluke. Yet studies show that individuals are often influenced more by information received from someone they know (such as a neighbor) in person than by information based on remote and anonymous sources (such as the 3,000 drivers surveyed, none of whom you personally know; Borgida & Nisbett, 1977; Hamill et al., 1980; Herr et al., 1991; Reyes et al., 1980; Shedler & Manis, 1986).

Evolutionary rationality of such a cognitive "bias" becomes immediately clear when one recalls that there were no surveys, opinion polls, government or commercial agencies that might commission large surveys, books, magazines—for example, *Consumer Reports*—television, radio, or the Internet in the ancestral environment. All information that our ancestors received came from other humans they personally knew; they never received information from anonymous sources or surveys of unknown individuals. There was no abstract, statistical information in the ancestral environment; all information was concrete, vivid, and personal. Humans are therefore evolutionarily designed to listen to and be influenced by information received from other humans, not by statistical information from anonymous sources to which the human brain is not adapted or for which it is not designed.

Sunk-cost fallacy

The sunk-cost fallacy "is the tendency to persist in a course of action because of prior investments in that option, either in terms of money, effort or time spent, despite a better alternative being currently available" (Magalhães & White, 2016, p. 340). It is one of the most pervasive cognitive and behavioral biases. Purely from the perspective of standard economics, decisions should be based strictly on future payoffs; rational actors choose the course of action that is most likely to produce the highest payoff or lowest cost. How much time or effort and how many resources they have invested in the course of action *in the past* should not at all influence how much more they are willing to invest in the *future*; the latter should be a function only of expected future payoffs. The sunk-cost fallacy is otherwise known as "the Concorde fallacy": "A government which has invested heavily in, for example, a supersonic airliner, is understandably reluctant to abandon it, even when sober judgment of future prospects suggests that it should do so" (Dawkins & Carlisle, 1976, p. 131).

Yet this economically irrational behavior is pervasive, not only among humans but also, as discussed above, among nonhuman species as phylogenetically remote from humans as ants (Czaczkes et al., 2018) and locusts (Pompilio et al., 2006), although there is some evidence that nonhuman animals and even human children do not commit the sunk-cost fallacy (Arkes & Ayton, 1999; Maestripieri & Alleva, 1991). Humans and other species continue to invest in a course of action in pursuit of a goal when they have heavily invested in it already. Thus, the sunk-cost fallacy is not merely a cognitive bias exhibited by Humans (as opposed to Econs), and its explanation must correspondingly go beyond the evolutionary limitations of the human brain.

Fortunately, comparative psychologists have already proposed an explanation for why the sunk-cost fallacy, although economically irrational, is nevertheless evolutionarily rational. Accounts variously known as within-trial contrast (Pattison et al., 2012; Zentall, 2010, 2013) or state-dependent learned valuation (Aw et al., 2011; Kacelnik & Marsh, 2002) suggest that organisms do not evaluate a reward for its intrinsic, objective value but instead subjectively in view of either the effort and time it has taken for them to obtain it (in the within-trial contrast account) or how much energetic change the reward makes when it is consumed (in the state-dependent learned-valuation account). The more effort and time it takes an organism to obtain a reward, or the more energetic difference its consumption makes, the more valuable the reward is subjectively perceived to be. Hence, organisms are more likely to persist in a course of action if they have invested more heavily in it because the ultimate reward will be perceived as more valuable relative to the investment and its consumption will have greater energetic value after longer and greater effort and time.

The important point to remember is that there were no price tags (or the concept of fungible money) in the ancestral environment. Today, if a loaf of bread costs $1, and the latest iPhone costs $1,000, anyone can easily tell that the iPhone is as valuable as a thousand loaves of bread. But, without price tags and the concept of fungible money, how can any of us tell whether an iPhone or a thousand loaves of bread is more valuable? How were our ancestors to tell whether one gazelle or seven hedgehogs were more valuable as dinner? In such cases, how much time or energy they expended to acquire the resource, or how much difference in energy the consumption of the resource makes, can serve as a useful guide for how valuable the resource is (Brosnan, 2018). The more time or energy one has expended in an attempt to acquire a resource, the more valuable it is, and thus the more time or energy one should correspondingly continue to expend in a further effort to acquire it. This may represent an irrational sunk-cost fallacy from the perspective of standard economics, but it makes perfect evolutionary sense in an environment in which the intrinsic value of a resource is uncertain and never clearly defined. I hasten to add, however, that the finding that children and some nonhuman species do not commit the sunk-cost fallacy (Arkes & Ayton, 1999; Maestripieri & Alleva, 1991), if replicable, may require a more complex evolutionary explanation for the sunk-cost fallacy.

Future discounting

Standard economics stipulates that rational actors discount the future exactly at the market rate of interest (Loewenstein & Thaler, 1989). If the annual interest rate is 1%, then rational actors prefer to receive $102 (or more) in a year rather than $100 today. Yet most individuals prefer to receive $100 today than $102 in a year. Humans discount the future more heavily than standard economics assumes.

For example, consumers prefer to purchase cheaper but less energy-efficient air conditioners (Hausman, 1979), refrigerators (Gately, 1980), and other heating and cooling equipment (Ruderman et al., 1987), although they can recoup the higher initial cost of purchase from the subsequent savings from lower energy costs in anywhere from 5 months to 5 years. Their purchase decisions imply a future discount rate anywhere from 5.1% to 825%, far above any reasonable annual interest rate. Why do individuals discount the future so heavily?

The evolutionary rationality of high future discounting becomes clear when one recalls that all resources in the ancestral environment were perishable and short-lived. Life in the ancestral environment was very uncertain and precarious, with no reliable medical care or social-welfare system to ensure a long, stable life. Meat and other food rot, and humans forget or die. If you do not eat all the food now or soon, it may not be edible in a week or two. If you do not cash in on the favor others owe you, people may not remember it in a year or two, or they may die. Only money and banks last forever (in most cases); none of the people or resources in the ancestral environment did. There were no written records or enforceable contracts, so all resources and exchanges depended on people's memory. If people forgot an earlier (necessarily verbal) agreement, changed their minds, or chose to renege on it, there was nothing you could do to hold them to it, unless you were physically stronger or socially more dominant. There was no one to provide formal, impartial third-party enforcement of agreements, such as the police or the courts. Nobody would have given you two hedgehogs in one year instead of one hedgehog today, and, if they did, you would be foolish—it would be evolutionarily irrational—to opt for the larger but delayed reward.

Extremely long odds

In an earlier section, I used the house-money effect as an example of an epicycle on epicycle, in which the usual epicycle of being risk averse in gains and risk seeking in losses is reversed when gamblers play with house money (earlier earnings; Thaler & Johnson, 1990). There is actually another epicycle on this particular epicycle. Individuals also reverse the usual pattern described in prospect theory when they are dealing with extremely long odds (Kahneman & Tversky, 1979). Lewis (2017, p. 269) wrote,

> If you told them [experimental subjects] that there was a one-in-a-billion chance that they'd win or lose a bunch of money, they behaved as if the odds were not one in a billion but one in ten thousand. They feared a one-in-a-billion chance of loss more than they should and attached more hope to a one-in-a-billion chance of gain than they should. People's emotional response to extremely long odds led them to reverse their usual taste for risk, and to become risk seeking when pursuing a long-shot gain and risk avoiding when faced with the extremely remote possibility of loss. (Which is why they bought both lottery tickets and insurance.)

Why do individuals fail to distinguish between odds of one in a billon and odds of one in ten thousand?

A natural span of human life, in the absence of modern advanced medical care, is about 70 years; anyone who survived infancy (and the high infant mortality rate) in the ancestral environment could expect to live to be about 70. Seventy years is 25,550 days. If something happened every day, our ancestors got to experience it about 25,000 times, many fewer during most of their lives or if the frequency of occurrence is less than daily. (Seventy years is also 3,640 weeks or 840 months.) There were very few things in the ancestral environment that our ancestors got to experience more than 10,000 times in their lifetimes. There is therefore no reason for evolution to build a mind that is capable of comprehending numbers larger than tens of thousands, let alone millions or billions. (It is instructive to recall that the Bible repeatedly expresses unimaginably large numbers, such as the number of angels, as "ten thousand times ten thousand" rather than 100 million; Daniel 7:10; Revelations 5:11.) If the odds are smaller than 1 in 25,000, it means that it will probably never happen in your lifetime, and there is no meaningful difference between one in a million and one in a billion. Treating any number larger than tens of thousands as equivalent made perfect sense in the ancestral environment, in which there were not a million of *anything* (except for angels). There would be no selective pressure to design a mind capable of comprehending billions, and there would be no selective pressure against a mind incapable of doing so (Cosmides & Tooby, 1996).

Loss aversion, endowment effect, risky bet premium, status quo bias

Loss aversion refers to the hypothesis that losses loom larger than gains, and a loss of a given magnitude has a stronger psychological impact than a gain of the same magnitude (Kahneman & Tversky, 1979). Thus, losing $100 feels worse than gaining $100 feels good. It was originally proposed to explain the anomaly of the risky bet premium. If you ask experimental subjects, "Suppose you were offered a risky bet that offered a 50% chance of losing $100 and a 50% chance of winning *X*. What is the least *X* would have to be for you to be willing to take this bet?", a majority of them would require *X* to be at least substantially larger than $100, whereas a risk-neutral Econ would require only $101. The premium (the amount in excess of $100 that the subjects would require to take the bet) is hypothesized to reflect their aversion to the possibility of loss.

Loss aversion was later invoked to explain the endowment effect, the idea that the possession of a good itself creates value. If you distribute a given good (say, a mug) to a random half of experimental subjects, owners demand a greater price to part with it than nonowners are willing to pay to acquire it (Kahneman et al., 1990; Knetsch & Sinden, 1984). In other words, the willingness to accept typically exceeds the willingness to pay for the identical good. This observation is also hypothesized to reflect the owners' aversion to loss.

However, as Gal (2006; Gal & Rucker, 2018) convincingly demonstrates, in all past empirical demonstrations of loss aversion, the gain/loss dimension was always confounded with the action/inaction dimension. To enter into a risky bet or an exchange of a good for money, individuals have to take some action, whereas the safer (loss-aversive) option always represented inaction. When researchers carefully separate the gain/loss dimension from the action/inaction dimension in cleverly designed experiments, it is action (vs. inaction) to which individuals are aversive, not loss (vs. gain; Gal & Rucker, 2018; Ritov & Baron, 1992).

Why are individuals aversive to action? Gal (2006) invokes the notion of psychological inertia to explain action aversion. Psychological inertia has long been invoked in psychological theory, starting with the discovery of the Zeigarnik effect (Zeigarnik, 1927) and its later applications in personality research (Atkinson, 1953; Atkinson & Birch, 1970; Lewin et al., 1935). Action typically requires a clear motive derived from a well-defined preference, but preferences are often fuzzy and ill-defined, as shown by Bem (1967) and Nisbett and Wilson (1970). Thus, in the absence of strong external forces, individuals are inertial and prefer inaction to action. Psychological inertia and action aversion, rather than loss aversion, can explain the endowment effect, the risky bet premium, and the status quo bias.

Although apparently unaware of the earlier work of Gal and colleagues (Gal, 2006; Gal & Rucker, 2018), Bruner et al. (2020) reach the same conclusion with their explicitly evolutionary model that the endowment effect emerges out of bias against trade (or "action" vs. "inaction" in Gal's language). Bruner et al. (2020) also show that such bias against trade ultimately stems from the fact that individuals are uncertain of the reproductive value of a given item. The fact that there are others who are willing to trade for the item suggests that its inherent value might be greater than the owner initially assumed, so it might be more prudent to hold on to it than to give it up. As I argue above, the inability to assess an item's inherent value, which was endemic and pervasive in the ancestral environment before the emergence of money as a fungible resource, likely underlies mental accounting and the sunk-cost fallacy and explains their potential evolutionary rationality. The uncertainty of an item's inherent value in the absence of money may therefore explain multiple "anomalies" discovered (but left unexplained) by behavioral economists.

Gal (2006) reminds us that the law of inertia is Newton's first law of motion, which in turn is rooted in calculus in mathematics. Mathematics is the universal language of science, and the laws of physics permeate the entire universe. Reductionism is a universal principle in science, and the hierarchy of sciences encompasses all sciences. Just as evolutionary biology is more fundamental than economics, mathematics and physics are far more fundamental than evolutionary biology. Gal (2006) hints that physics, not evolutionary biology, may ultimately explain loss aversion. Thus, the ultimate origins of some of the cognitive biases uncovered by behavioral economics may possibly predate life itself.

If Standard Economics Is Fundamentally Wrong, Why Does It Sometimes Succeed?

Although standard economics frequently produces incorrect predictions, as decades of behavioral economic experiments have shown, it is undeniable that it has also succeeded in making accurate predictions. In fact, economics is widely regarded, by both economists and others, as "the Queen of the Social Sciences" (Samuelson, 1948), the most successful social science of all. It is the only social science for which a Nobel prize is conferred. If the standard economic model of human behavior is fundamentally incorrect, how can economics ever achieve any predictive success?

I believe there are at least three different reasons that account for economics' empirical successes. First, even incorrect theories make accurate predictions sometimes. Geocentrism, and assuming that the earth is flat, still allow you to drive from Chicago to Detroit without any problems (the two-dimensional Rand McNally road map of the United States is nearly perfectly accurate), and geocentrism allows you to predict when the next full moon will be with perfect accuracy. Another fundamental paradigm shift in science is more illustrative. To this day, engineers design elevators and airplanes with calculations derived from Newtonian classical mechanics, even though it is fundamentally incorrect, because elevators and airplanes do not remotely approach the speed of light, at which point predictions derived from Newtonian mechanics and the (scientifically correct) special relativity diverge. Likewise, standard economics is still good enough and produces close enough approximations and predictions for human behavior in domains that are biologically and evolutionarily unimportant (mostly matters involving money) but not in domains that are biologically and evolutionarily important: life, sex, and reproductive success.

Second, corporate executives, managers, entrepreneurs, and other individuals sometimes behave economically rationally, in accordance with standard economic theory, because they have studied economics. Individuals who study economics can behave economically rationally in the same sense that individuals who study moral philosophy can behave morally and individuals who read the Bible can behave as good Christians. They are following prescriptions; they know what the "right" behavior is. College students who have studied economics are more likely to behave rationally, according to the principles of standard economics (Frank et al., 1993; Marwell & Ames, 1981). And managers and executives who run organizations and corporations are very likely to have studied economics because economics is the predominant discipline in all business schools (Kanazawa, 2006). In this sense, economics is *creating* the world in which its theories are supported. If all the evolutionary biologists in the world suddenly disappeared, and nobody taught evolution in schools, evolution still took place and will take place. If all the economists in the world suddenly disappeared, and nobody taught economics in business schools, the world in which their theories are empirically supported in large part disappears.

Economic studies of auctions (McAfee & McMillan, 1987) provide another example of how economists literally create the world in which their theories of rational behavior are supported. Standard auctions of the kind one might observe in an auction house such as Sotheby's to auction off collectible art (known technically as "the English auction") existed before (and without) standard economics. But economists have since invented all types of more complicated auctions, such as the first-price sealed-bid auction or the second-price sealed-bid auction (the latter known as the Vickrey auction, named after the economist William Vickrey, who won the Nobel prize in 1996 for inventing the complicated auction) to test their standard economic prediction about rational behavior under asymmetric information (Vickrey, 1961). The auctions they study today, such as the second-price sealed-bid auctions, would not exist without economics. The economists are thus creating a world in which their theories are supported.

Finally, standard economic theories are often tested with relatively intelligent experimental subjects, such as college students, business people, and corporate executives (who run and make decisions for firms and corporations whose organizational behavior is studied by economists). As explained below, for evolutionary reasons, more intelligent individuals are better able to overcome the evolutionary constraints of their brains and act economically rationally, although it is evolutionarily unnatural to do so. Evidence suggests that more intelligent individuals often go against their evolutionary design and do "unnatural" things (Kanazawa, 2012). Behaving economically rationally may be one of the ways that more intelligent individuals behave unnaturally.

Novel Predictions

What does the new foundation of evolutionary biology and psychology contribute to the understanding of human behavior that standard economics cannot? What novel predictions does this new perspective offer that have not been already offered by behavioral economics? One source of novel prediction from this perspective is the effect of general intelligence on economic behavior, which has hitherto been entirely neglected by behavioral economists.

Because general intelligence likely evolved to solve evolutionarily novel problems, not evolutionarily familiar problems (Kanazawa, 2004a), more intelligent individuals are better able than less intelligent individuals to solve evolutionarily novel problems but not evolutionarily familiar problems (such as mating, parenting, and friendships), and they are also more likely to acquire and espouse evolutionarily novel preferences and values that our ancestors did not have (Kanazawa, 2010a, 2010b). As a result, the Savanna Principle (Kanazawa, 2004b) about the evolutionary constraints on the human brain holds less strongly among more intelligent individuals than among less intelligent individuals. More intelligent individuals are less constrained by their evolutionary design of the human brain; more intelligent individuals are therefore more likely to do unnatural things from the evolutionary perspective.

The evolutionary origin of general intelligence thus leads to the prediction that all of the cognitive biases and heuristics that behavioral economists have discovered and I explain above as consequences of evolutionary rationality hold less strongly among more intelligent individuals. In other words, more intelligent individuals are more likely to be economically rational and less likely to be evolutionarily rational.

Evidence indeed suggests, as predicted, that more intelligent individuals are less likely to commit cognitive errors (Stanovich, 1999; Stanovich & West, 2002). And more intelligent individuals are more likely to behave rationally and defect in one-shot Prisoner's Dilemma games, as predicted by noncooperative game theory (Kanazawa & Fontaine, 2013). I acknowledge, however, that the anecdotes given above of even the best economists' failure to abide by the very economic principles that they publicly espouse in their work seem to contradict this prediction. Other predictions from this hypothesis await development and empirical confirmation, as do other possible implications of evolutionary biology as a model of human behavior.

Conclusion

Economics aspires to be a science, and science is empirical and explanatory. Economics fails as a science because many of its predictions are not supported by empirical data. Standard economics simply does not explain nature as it happens. In this sense, standard economics is more prescriptive than descriptive or explanatory, and prescriptive theories, such as philosophy, religion, and morality, belong in the humanities, not science. Standard economics is more science fiction than science. Just as all of the details of *Star Wars*—such as the emotional conflict between Darth Vader and Luke Skywalker—make perfect sense *if* you accept the premise that the Empire, the Jedis, and the rebels exist and that (spoiler alert) Skywalker is the long-lost son of Vader, everything in standard economics makes perfect sense *if* you accept the assumption that human actors are Econs. Take away the premise and everything else collapses. George Lucas created the world in which his stories make sense; likewise, as noted earlier, economists through their education and public discourse are creating the world in which their theories are supported rather than describing and explaining nature as it exists, which is the purpose of science. If Lucas did not tell us that Skywalker was Vader's son, nothing in *Star Wars* makes sense. If economists did not tell us, by fiat, that humans are economically rational, nothing in economics makes sense. Economists calling observed and documented human behavior irrational because it does not conform to standard economic theory of rational behavior is like Lucas saying that there is something wrong with humans because the Force is not with them.

Standard economics is collapsing under the weight of its epicycles and epicycles on epicycles, represented by the voluminous research findings in the field of behavioral economics. Its basic tenets are becoming increasingly untenable as a result of more and more observations that deviate from the theoretical assumptions of standard economics and the need to add more and more epicycles. Yet the behavioral economics that has produced these anomalous observations represents merely epicycles on standard economics and cannot itself replace standard economics because it has no theory of its own. Just as it was time in 1617 to abandon geocentrism with circular orbits for heliocentrism with elliptical orbits, it is past time now after 2017 to abandon standard economics and its assumptions of economic rationality for the biologically and evolutionarily correct model of human behavior represented by evolutionary biology and psychology. Replace the assumptions of *Homo economicus* and economic rationality with the observation that humans are evolved animals with biological and evolutionary rationality, and all of the paradoxes and anomalies in standard economics documented by Thaler (1992) disappear, just as heliocentrism and elliptical orbits made all the epicycles disappear four centuries earlier.

Transparency

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