



Behavioral economics and climate change policy[☆]

John M. Gowdy*

Rittenhouse Professor of Humanities and Social Science, Department of Economics, Rensselaer Polytechnic Institute, Troy, NY 12180-3590, United States

ARTICLE INFO

Article history:

Received 21 March 2007

Received in revised form 28 June 2008

Accepted 29 June 2008

Available online 9 July 2008

JEL classification:

C7

D6

D7

D8

Q2

Keywords:

Behavioral economics

Climate change

Cooperative behavior

Generalized Darwinism

Neuroeconomics

Rational actor model

ABSTRACT

The policy recommendations of most economists are based on the *rational actor* model. The emphasis is on achieving efficient allocation by insuring that property rights are completely assigned and that market failures are corrected. This paper takes the position that so-called behavioral "anomalies" are central to human decision-making and, therefore, should be the starting point for effective economic policies. This contention is supported by game theory experiments involving humans and closely related primates. This research suggests that the standard economic approach to climate change policy, with its focus on narrowly rational, self-regarding responses to monetary incentives, is seriously flawed.

© 2008 Elsevier B.V. All rights reserved.

1. Introduction

Behavioral research has fundamentally changed the field of economics by putting it on a firm experimental basis (Camerer et al., 2004; Gintis, 2007). The axioms of consumer choice, the starting point of traditional economic theory, have been re-cast as testable hypotheses, and these assumptions have come up short as defendable scientific characterizations of human behavior. It is no longer tenable for economists to claim that the self-regarding, rational actor¹ model offers a satisfactory description of human decision-making. Nor do humans consistently act "as if" they obey the laws of rational choice theory, as the evidence discussed below shows. The implications for economic policy are enormous but have just begun to be explored.

In its early days behavioral economics concentrated on revealing various shortcomings of the standard model of economic choice. Recently the field has moved from merely reacting against the rational actor model to identifying behavioral

[☆] An earlier version of this paper was presented as the Keynote lecture of the Association for Social Economics, ASSA meetings, Chicago, 4 January 2007.

* Tel.: +1 518 276 8094; fax: +1 518 276 2235.

E-mail address: gowdyj@rpi.edu.

¹ The fact that the field of economics is changing so rapidly means that terms that were once good descriptions of basic concepts are no longer adequate. I use the term "rational actor" to describe to kind of behavior also attributed to *Homo economicus* or economic man. Other terms for the traditional economic model include "rational choice theory", "the canonical model" (Henrich et al., 2001), or the "axioms of consumer choice". Gintis (2000) uses the term "rational agent" but in a way so as to include a much wider array of human behaviors than the once standard economic model. I use the term "Walrasian" to describe the general equilibrium system of traditional economics with its key assumptions of self-regarding rational actors and competitive equilibrium.

regularities that might form the basis for a new, more realistic model of human decision-making. Experiments such as the Ultimatum Game and the Public Goods Game have established a number of regularities in human behavior such as loss aversion, habituation, pure altruism, altruistic punishment, and hyperbolic discounting of the future. These behavioral patterns have been confirmed by neurological experiments showing how behavior is reflected in brain activity.

A shortcoming of much of the behavioral economics literature is that it still considers violations of the rational actor model to be “anomalies.” “Irrational” human behavior is frequently explained by a kind of tug-of-war between the “rational” part of the brain, the cerebral cortex, and some other more primitive “emotional” part of the brain—“The overriding of deliberation by the influence of visceral factors . . .” as Loewenstein (2004, 691) puts it. The implication is that humans try to act rationally, but they are sometimes dragged down by their “animal” instincts. The vast majority of evolutionary biologists and neurobiologists reject this view.² The emerging view of cognition is that the human brain is a unified, highly evolved system with complementary, rather than conflicting, components (Glimcher et al., 2005). Furthermore, it is the “anomalies” (the deviations from the rational actor model) that make humans almost unique in the animal kingdom in their degree of cultural complexity. Ironically, the rational actor model seems to be most appropriate for animals with limited cognitive ability and perhaps humans making the simplest kinds of choices. For the most important decisions humans make, culture, institutions, and give-and-take interactions are critical and should be central to any behavioral model.

This paper argues that the neuroscience of choice can take behavioral economics a step further to offer a unified³ model of decision making that can lay the foundations for a science-based policy framework for critical issues involving cross-cultural cooperation and inter-generational transfers. Global climate change is used as an example of how sustainability policies might be informed by contemporary theories of human choice.

2. New insights into human behavior

Experimental results from behavioral economics, evolutionary game theory and neuroscience have firmly established that human choice is a social, not self-regarding, phenomenon. Two broad principles have emerge from the literature (1) human decision-making cannot be accurately predicted without reference to social context, and (2) regular patterns of decision-making, including responses to rewards and punishments, can be predicted both within particular cultures and across cultures.

One of the most important contributions to behavioral economics was the Ultimatum Game⁴ (UG) formulated 25 years ago by GÜTH et al. (1982). Like the Prisoner's Dilemma game before it, the UG helped revolutionize the way economists think about economic decision-making. Results from this game as well as from a variety of other game theoretic experiments showed that, in a variety of settings and under a variety of assumptions, other-regarding motives are a better predictor of behavior than those embodied in *Homo economicus*. Humans regularly exhibit a culturally conditioned sense of fairness, and they are willing to enforce cultural norms even at economic cost to themselves. Cross-cultural UG experiments also show that cultural norms vary and that they dramatically affect the average amount offered in the game and the rates of rejection (Henrich et al., 2001). A striking result of numerous UG experiments is that the model of rational economic man is not supported in any culture studied (Henrich et al., 2001).

Also relevant to the study of human decision-making is a growing body of evidence from (non-human) animal experiments. These experiments show two important things. First, social animals, such as primates, also have a sense of fairness and a tendency to cooperate, even at a cost to themselves. Second, “lower” animals do appear to behave in accordance with the rational actor model. They are self-regarding in evaluating payoffs, they are not susceptible to the sunk cost effect, and they apparently evaluate payoffs according to expected utility theory.

2.1. The behavior of social animals

Melis et al. (2006) played a cooperation game with chimpanzees at the Ngamba Island Chimpanzee Sanctuary in Uganda. A feeding platform with two metal rings was placed outside a testing room cage with a rope threaded through the rings

² Referring to the idea of economists that “irrational” behavior is the product of ancient emotional systems within the brain, Glimcher et al. (2005, p. 252) write, “What we cannot stress strongly enough is that the vast majority of evolutionary biologists and neurobiologists reject this view. There are probably two principle reasons that biologists reject this dualist view of the nervous system: one neurobiological and one behavioral. First there is no neurobiological evidence that emotional and non-emotional systems are fully distinct in the architecture of the human brain. Second there is no evidence that rational and irrational behaviors are the products of two distinct brain systems, one of which is uniquely rational and one of which is uniquely irrational.”

³ Some readers of this paper objected to the notion of a “unified model” of human behavior. I use the term only to mean that the various kinds of models used by economists, sociologists, anthropologists, decision scientists, and so on should not be flatly contradictory as they are now. This does not contradict, for example, Norgaard's (1989 and 2006) notion of “methodological pluralism,” but it does mean weeding out, using the scientific method where possible, theories of behavior falsified by empirical evidence.

⁴ In the Ultimatum Game a leader offers one of two participants a certain sum of money and instructs that participant to share it with the second player. The second player can either accept the offer or reject it (in which case neither player gets anything). If the players behave according to model of *Homo economicus*, the first player should offer the minimum amount and the second player should accept any positive offer. Results from the game show, however, that the majority of proposers in Western countries offer between 40 and 50 percent of the total and that offers under 30 percent of the total are usually rejected because they are not “fair” (Nowak et al., 2000). These results have held up even when the game is played with substantial amounts of real money (Gowdy et al., 2003).

and the two ends of the rope in the test room cage. If the chimpanzee(s) pulled only on one end of the rope, the rope passed through the rings and the food was not obtained. Only if two pulled together could the platform be pulled forward and the food obtained. During repeated tests, the chimpanzees were allowed to recruit partners of their own choice and they quickly learned to recruit those who were the best collaborators. Kin selection is not involved since the chimpanzees at the sanctuary are unrelated orphans from the wild. The authors observe (p. 1297), "Therefore, recognizing when collaboration is necessary and determining who is the best collaborative partner are skills shared by both chimpanzees and humans, so such skills may have been present in their common ancestor before humans evolved their own complex forms of collaboration".

Economists tend to be skeptical of altruistic behavior because of the "free rider" problem. Self-regarding individuals can out-compete altruists by taking advantage of their generosity. As an answer to this objection, [Henrich et al. \(2006, p. 1767\)](#) propose that altruism arose in humans hand-in-hand with punishment. Altruistic punishment, punishing others for violating social norms even at cost to oneself, is one-way humans deal with free riders and make cooperation work. Apparently, punishing those who do not cooperate actually stimulates the same pleasure centers in the brain that are activated by, for example, eating something sweet ([Vogel, 2004, p. 1131](#)). Some evidence indicates that punishing behavior is present in chimpanzees. In one experiment semi-wild chimpanzees were fed at a regular time only after all the chimpanzees in the compound came to the feeding station. Late-comers held up the feeding for all the chimps, and these stragglers were punished with hitting and biting.

In terms of standard economic theory, the question is not whether humans (or other animals) are selfish or altruistic but whether they are *other-regarding*. If individuals evaluate their payoffs based on what others get, this violates the conditions for Pareto efficiency in the standard model. Other-regarding behavior may be altruistic, envious or any other socially conditioned response to others. For example, researchers found that in cooperation games with an opportunity to punish, subjects from Belarus and Russia punished not only defectors but also strong cooperators ([Vogel, 2004](#)).

2.2. Are "lower" animals more rational than humans?

The view of the human rational actor as a sophisticated decision maker has also taken a blow from studies of animals with more limited cognitive ability. Regarding the claims for human "rationality", it is ironic that a large body of evidence suggests that "lower" animals act more in accordance with the economic model of rational choice than humans do. In a classic experiment, [Harper \(1982\)](#) tested the ability of a flock of ducks to achieve a stable Nash equilibrium when fed balls of bread. Every morning two researchers would stand on the bank of the pond where the ducks were and throw out 5 g dough balls at different intervals. Expected utility theory would predict that the ducks would distribute themselves between the two feeders in such a way that, $N1/r1 = N2/r2$, where Ni is the number of ducks and ri is the expected (bread) payoff from standing in front of one of the feeders. Thus if there are 33 ducks participating and if one experimenter throws a 5 g ball of dough every 15 s and the other experimenter throws a 5 g ball of dough every 30 s, there should be 22 ducks in front of the first experimenter and 11 in front of the other. In fact this is what happened. The ducks re-arranged their numbers efficiently as the payoffs were changed. Furthermore, if the experimenters changed the speed of throwing the dough balls, the ducks would quickly and efficiently readjust their numbers. [Glimscher \(2002, p. 329\)](#) writes,

One thing that was particularly striking about this result was the speed at which the ducks achieved this assortment. After 90 s of breadball throwing, as few as ten breadballs have been dispersed. Long before half the ducks have obtained even a single breadball, they have produced a precise equilibrium solution.

Another well-known behavioral "anomaly" is the sunk cost effect. Ignoring unrecoverable past expenditures is one of the common admonishments for students learning to "think like an economist", that is to behave in a sophisticated rational way ([Frank and Bernanke, 2004](#)). But once again, actual human behavior consistently deviates from the rational actor model. A number of experiments have demonstrated that human decisions are strongly influenced by sunk costs ([Whyte, 1993](#)). It appears, however, that ignoring sunk costs is a characteristic of the behavior of lower animals, but not humans ([Arkes and Ayton, 1999](#)). [Fantino \(2004\)](#) performed a simple "investing" experiment with college students and pigeons. Both were rewarded with money or food for pressing a computer keyboard an undetermined number of times until an award was given. Pressing some of the keys resulted in an award while pressing others produced no reward. The experiment was designed to model a bad investment in which the chances of success diminished as the number of responses increased. The more times a key was pressed with no reward forthcoming, the less likely further pressing would produce an award. In the experiment, the pigeons quickly switched from one key to another if an award failed to appear, while the students kept repeatedly pressing the same key, indicating that pigeons were less susceptible than students to the sunk cost effect. In another sunk cost experiment [Maestripieri and Alleva \(1991\)](#) tested the behavior of mother mice in defending their young and found that the aggressiveness defensive behavior depended on the number of offspring in the litter, not the amount of time invested in caring for them.

The animal behavior literature, together with observations of human behavior, suggests that letting sunk costs influence decision-making is a trait that must have something to do with human characteristics such as the presence of complex capital investments and complex institutions in human societies. It is sometimes argued that although individuals may exhibit irrational behavior, such behavior is corrected in groups (as in the rational expectations literature). In fact, research shows that groups are probably more susceptible to the sunk cost effect than are individuals ([Whyte, 1993](#)).

2.3. Crowding out by monetary incentives

A growing body of experimental evidence indicates that monetary incentives can be a deterrent to cooperative behavior (Frey, 1997; Frey and Oberholzer-Gee, 1997). An often cited example is the finding that paying blood donors significantly reduces blood donations (Titmuss, 1971). A recent experiment found that the mere mention of "money" had a negative effect on sociality. Vohs et al. (2006) performed several experiments that compared various kinds of social behavior in groups of people who were first given reminders of "money" with groups given a "non-money" reminder. For example, in one experiment participants were asked to unscramble jumbled words to make phrases. In the money group the phrases involved some concept of money, like "a high-paying salary is important." In the control group the phrases were neutral, like "it is cold outside". This reinforced thinking in terms of money in the experimental group but not the control group. The groups were then subjected to nine experiments designed to test the effects of exposure to money on "self-sufficiency" and helpful behavior. In one experiment subjects were given \$2 in quarters that they were told was left over from an earlier experiment. At the end of the word scrambling game they were offered the chance to put money in a box to denote to needy students. Those exposed to reminders of money gave substantially less to the charity. In another experiment subjects reminded of money were less likely to ask for help in performing a complicated task. In another test, subjects were asked to sit at desks and fill out a questionnaire. Some desks faced a poster with a picture of money, and others faced a poster showing flowers or a seascape. They were then asked to choose between a reward characterized as a "group" or "individual" activity, for example, individual cooking lessons versus a dinner for four. Those exposed to the money poster were more likely to pick individual activities. The authors summarize the results as follows (p. 1154),

Relative to participants primed with neutral concepts, participants primed with money preferred to stay alone, work alone, and put more physical distance between themselves and a new acquaintance When reminded of money, people would want to be free from dependency and would also prefer that others not depend on them.

2.4. Neuroscience confirmation of behavioral "anomalies"

2.4.1. Habituation

It has long been known that two groups of neurons, in the *ventral tegmental* and the *substantia nigra pars compacta* areas, and the dopamine they release, are critical for reinforcing certain kinds of behavior (Schultz et al., 1997; Glimcher et al., 2005; Schultz, 2002). Schultz measured the activity of these neurons while thirsty monkeys sat quietly and listened for a tone that was followed by a squirt of fruit juice into their mouths. After a period of a fixed, steady amount of juice, the amount of juice was doubled without warning. The rate of neuron firing went from about 3 to 80 per second. As this new magnitude of reward was repeated the firing rate returned to the baseline rate of 3 firings per second. The opposite happened when the reward was reduced without warning. The firing rate dropped dramatically, but then returned to the baseline rate of 3 firings per second.

2.4.2. The framing effect

Consistency in choice is the hallmark of rational economic man, and it implies that evaluation of choices will be unaffected by the manner in which the choices are framed. This view was challenged by Kahneman and Tversky (1979) in their formulation of "prospect theory"; that is, people evaluate changes in terms of a reference point. The "framing effect" means that the frame of reference may change according to how a particular choice is presented, and this will affect the payoff decision. This effect has been confirmed in numerous experiments, and it too seems to have a neurological basis (Miller, 2006). De Martino et al. (2006) used functional magnetic resonance imaging (fMRI)⁵ to look at the neurological effects of framing in a simple experiment. A group of 20 subjects were asked to choose between identical outcomes framed differently. They were told first that they would initially receive £50. They then had to choose between a "sure" option and a "gamble" option. The sure option was presented in two ways, either as a gain (say keep £20 of the £50) or as a loss (say lose £30 of the £50). The gamble option was presented in the same way in both cases: a pie chart showing the probability of winning or losing. People responded differently depending on how the question was framed, and this was reflected in fMRI images. Different parts of the brain lit up depending on how the question was framed.

The fact that the framing effect found in this experiment had a neurological basis was confirmed:

Our data provide a neurobiological account of the framing effect, both within and across individuals. Increased activation in the amygdala was associated with subjects' tendency to be risk-averse in the Gain frame and risk-seeking in the Loss frame, supporting the hypothesis that the framing effect is driven by an affect heuristic underwritten by an emotional system. (De Martino et al., p. 686)

The neural basis for loss aversion was also confirmed by Tom et al. (2007). They found that in order for people to accept a 50–50 gamble the potential gain needs to be twice as high as the potential loss. They discovered that the brain regions that evaluated potential gains and losses were more sensitive to losses. Also, between-subject differences in loss aversion reflected between-subject differences in neural responses.

⁵ It should be pointed out that fMRI techniques measure blood flow and oxygen consumption rather than neural firings and the resolution is rather poor.

These neurological findings may not add anything new to the catalog of behavioral patterns observed by behavioral economics, but they do show that they are more than “anomalies”. These observed behaviors are not random mistakes but rather are a part of our neurological inheritance.

2.4.3. The relative income effect

[Brosnan and de Wall \(2003\)](#) found that brown capuchin monkeys (*Cebus paella*) exhibit a strong aversion to inequity. In one experiment, monkeys rejected rewards for performing a simple task if they witnessed another monkey receiving a more desirable reward for performing the same task. Pairs of monkeys were trained to exchange a small rock with a human in return for receiving a piece of cucumber. When one monkey saw another receiving a more desirable reward (a grape) the monkey would not only refuse to participate in further exchanges, but it would also frequently refuse to eat the cucumber reward, sometimes even throwing it toward the human experimenter.

People judge fairness based both on the distribution of gains and on the possible alternatives to a given outcome. Capuchin monkeys, too, seem to measure reward in relative terms, comparing their own rewards with those available, and their own efforts with those of others. (Brosnan and de Waal, p. 299)

2.4.4. Threshold effects

In a study of how rhesus monkeys respond in a color matching experiment, [Schall and Thompson \(1999\)](#) found a correlation between neural firing rates and making a physical movement. Thirsty monkeys were trained to stare at a cross in the center of a blank display. Then a circle of eight spots were illuminated, seven in one color and the eighth in another. If the monkey moved his gaze to look at the “oddball” color, he was rewarded with a squirt of juice. When the oddball color was identified, neural firing rates began to increase at the location in the brain encoding the oddball. Only after the neural firing rate passes an apparently fixed threshold did the monkey move his gaze. [Glimcher et al. \(2005\)](#) postulate that the decision making brain forms a kind of topological map that encodes something like the relative expected gains of each possible choice. Actually making a choice (taking an action) depends on the strength of the signal relating to that particular action (the neural firing threshold).

2.5. Rational choice and actual human behavior

The view is widespread that animal behavior justifies the economic rational actor model. [Gintis \(2007, p. 7\)](#), for example, argues that the assumption of choice consistency among humans is justified by animal behavior: “Economic and biological theory thus have a natural affinity; the choice consistency on which the rational actor model of economic theory depends is rendered plausible by biological evolutionary theory, and the optimization techniques pioneered by economic theorists are routinely applied and extended by biologists in modeling the behavior of a vast array of organisms.” Others take the view that animal studies show that the rational choice model is inappropriate to describe all but the simplest kinds of human decision making. [Camerer et al. \(2005, p. 55\)](#) write,

Our view is that establishing a neural basis for some rational choice principles will not necessarily vindicate the approach as widely applied to *humans* . . . Ironically, rational choice models might therefore be most useful in thinking about the simplest kinds of decisions humans and other species make—Involving perceptual tradeoffs, motor movements, foraging for food and so forth—and prove least useful in thinking about abstract, complex, long-term tradeoffs which are the traditional province of economic theory.

Far from describing higher-order, complex human behavior, the axiomatic rational choice model strips away everything that makes humans unique as highly intelligent social animals. [Nelson \(2005, 264\)](#) puts it succinctly:

Defining economics as the study of *rational choice*, neoclassical economics treats human physical bodies, their needs, and their evolved actual psychology of thought and action as rather irrelevant. The notion that humans are created as rational decision-makers is, from a physical anthropology point of view, just as ludicrous as the notion that humans were created on the sixth day.

Our very complex, other-regarding, altruistic, empathetic behavior is what makes humans unique, and understanding this behavior is the key to formulating effective economic policies having complicated and long-lasting consequences.

3. It is possible to establish compatible theories of human behavior within the social sciences?

One of the great scientific achievements of the twentieth century was the unification of the natural sciences—unification in the sense that, although very different models are used, the basic understandings of such diverse fields as biology, physics and chemistry were made to be *compatible* ([Gintis, 2007](#)). For example, although they describe very different processes, the theory of natural selection does not contradict the laws of thermodynamics. The situation in the social sciences is quite different. Theories of individual human behavior held by economists, sociologists, anthropologists, and decision scientists are contradictory and incompatible. [Gintis \(2007, p. 2\)](#) writes,

The behavioral sciences all include models of individual human behavior. Therefore, these models should be compatible, and indeed, there should be a common underlying model, enriched in different ways to meet the particular needs of each discipline. Realizing this goal at present cannot be easily attained, since the various behavioral disciplines currently have *incompatible* models. Yet, recent theoretical and empirical developments have created the conditions for rendering coherent the areas of overlap of the various behavioral disciplines, as outlined in this paper.

Making the economic model of behavior compatible with established facts from other behavioral sciences will not be an easy task. As Pesendorfer (2006, p. 712) points out, behavioral economics is largely organized around the failures of standard economics rather than being a stand-alone alternative. But an alternative is clearly needed. Results from behavioral economics, game theory, and neuroscience indicate that simply modifying the basic *Homo economicus* assumptions will not yield a satisfactory model of human behavior. Progress can be made by focusing our attention on observing how and why people make choices, identifying consistent patterns in these observed choices, and determining how these choices might be predicted (Rieskamp et al., 2006).

What sort of general framework will contain a consistent theory of human decision-making? How can the findings from behavioral economics be placed in a framework that would provide policy guidance to sustainability issues? First of all there seems to be a movement in philosophy and in economic methodology toward *methodological pragmatism* (Bromley, 2006; Hodgson, 2004; Howarth and Wilson, 2006; Norgaard, 2006; Norton, 2005; Searle, 2001). Grounding behavioral theories in methodological pragmatism avoids the excesses of both positivist reductionism and the morass of post-modern relativism. Economic behavior can be understood by observing the actions of actual individual agents and the structural context within which they operate.

There also seems to be a movement toward accepting a single useful operational structure to analyze human behavior, namely, *generalized Darwinism*. The basic idea is that social change as well as biological evolution can be understood by applying the Darwinian framework of variation, inheritance and selection (Gintis, 2006; Hodgson, 2004; Richerson and Boyd, 2005). In Hodgson's (p. 450) words, "Darwinism combines a general theoretical framework with pointers to historically and context specific analysis that is highly relevant for the social sciences." For economists, this involves a conceptual shift from comparative statics to causal, hierarchical, and synergistic processes. When applied to social behavior, Darwin's general principles need to be modified to place much more emphasis on experience and volition (Paavola and Adger, 2006). Generalized Darwinism does not imply a purely materialistic approach (Hodgson). The term is used here as a broad metaphor on which to base a theoretical superstructure for research designs to gauge the efficacy of public policy. In this sense, generalized Darwinism is compatible with behavioral economics in that it illuminates the role of incentives in "selecting" kinds of human behavior.

The framework of variation, inheritance and selection is compatible with the behavioral literature in calling into question the over-reliance on price incentives as a behavioral selection mechanism. An on-going debate in ecological economics and environmental ethics is over the role of prices in environmental protection policies. On one hand, there is almost a cottage industry in putting prices on everything from biodiversity to scenic views. On the other hand, there is a large literature claiming that environmental policy should be based on principles other than market efficiency through price signals, for example, appealing to social conscience, ethics, and norms of fairness (Bromley, 2006; McCauley, 2006; Norton, 2005; O'Neill and Spash, 2000; Sagoff, 1988). As discussed above, using monetary incentives to promote the social good can have a perverse effect. One effect of money is to make people more individualistic and less social. Seriously addressing global warming will involve collective, social decision making on an unprecedented scale.

The emphasis in this section has been on individual behavior, but results from behavioral economics show clearly that individual choices are culturally conditioned. The possibility for consensus for collective action depends on its compatibility with institutional norms. Generalized Darwinism recognizes that patterns of human behavior are selected and retained on the basis of their compatibility with approved ways of doing things. At any given time, people are rewarded and punished according to how they behave with respect to social norms. Of course within any particular society cultural norms vary with context, and one norm is frequently in conflict with other norms. In market economies, accumulating personal wealth is respected, but so too is acting charitably. Global warming is at present a classic "tragedy of the commons" problem.⁶ Climate change policy based on behavioral economics would identify the incentives for selfish behavior in the "atmospheric commons" and then look for ways to minimize incentives for this sort of behavior and ways to maximize those for cooperative solutions.

4. Global climate change

Understanding how humans make decisions and respond to incentives is much more than an interesting academic question. It may prove to be the key to the quality of human life in the decades and centuries to come. It is likely that responding to rapid climate change will be the major challenge our civilization faces in the coming decades and centuries.

⁶ Garrett Hardin's classic 1968 paper (Hardin, 1968) continues to provide insights into the problem of free riding and common property resources, but has not held up well in light of behavioral economics, evolutionary psychology and game theory. "Common" property was actually well-regulated in traditional societies to prevent overuse. Concessions to the common good, if enforced by effective punishment, can mitigate the free riding problem.

Table 1

Carbon in the environment and carbon stored as fossil fuel

| Reservoir | Size (gigatons) |
|--|-----------------|
| Atmosphere | 750 |
| Forests | 610 |
| Soils | 1580 |
| Surface ocean | 1020 |
| Deep ocean | 38100 |
| Total active carbon in the environment | 3960 |
| Fossil fuels | |
| Coal | 4000 |
| Oil | 500 |
| Natural gas | 500 |
| Total fossil fuel carbon | 5000 |

Adapted from Kasting (1998); similar numbers are given in the IPCC's fourth assessment report, 2007.

As a result of fossil fuel burning and deforestation, the global average surface temperature rose by about 0.7 °C in the past hundred years, and the rate of increase appears to be accelerating. Global average temperatures are projected to increase by between 1.4 °C and 5.8 °C by 2100 and to continue to rise long after that (Dow and Downing, 2006, p. 37) because of the long residence time of CO₂ in the atmosphere (more than 100 years).

To put this projected temperature change in perspective, one has to go back 55 million years to find earth temperatures that high.⁷ The probable consequences of global warming are well known and include sea level rise, increased droughts and floods, more frequent and intense forest fires, more intense storms, more extreme heat episodes, agricultural disruption, the spread of infectious diseases, and biodiversity loss. Beyond these certain effects is the possibility of runaway positive feedback effects from, for example, the release of massive amounts of methane from permafrost and marine clathrates buried under the ocean floor (Flannery, 2005, p. 199).

Until the 20th century CO₂ levels were under 300 ppm for the past 650,000 years, at least. The pre-fossil fuel era level was about 280 ppm. In the Spring of 2007 it was 387 ppm, and with business-as-usual it is projected to increase to 600 ppm by 2050. CO₂ levels could reach 2000 ppm in several centuries if the readily available coal, petroleum and natural gas are burned (Kump, 2002). Kasting (1998) believes that the most likely scenario is that atmospheric CO₂ will peak at about 1200 ppm sometime in the next century. A climate-carbon model developed by Bala et al. (2005) has the CO₂ peak occurring around the year 2300 at 1400 ppm. As shown in Table 1 about 4000 gigatons (10⁹ tons) of carbon are stored in the atmosphere, forests, soils, and the upper ocean. There is much more carbon in the deep ocean, but this does not interact with the rest on a timescale relevant to this discussion (Kasting, 1998). About 5000 gigatons of carbon is stored in accessible fossil fuels, compared to 750 gigatons in the atmosphere. About one-half the carbon released by fossil fuel burning ends up in the atmosphere. Deforestation also releases carbon and recently this activity contributes about one third of the annual human-caused additions to atmospheric CO₂. The burning of petroleum and natural gas is a major problem since there is more carbon stored in these two fuels than there is in the atmosphere, but from Table 1 it is clear that the biggest problem is coal. About 80 percent of the world's fossil fuel carbon reserves are in the form of coal. Known coal reserves contain about five times as much carbon as is now in the atmosphere. If most of these reserves are burned without CO₂ controls, the results will likely be severe (Caldeira and Kasting, 1993).

Most coal is burned to generate electricity. What are the options for replacing this vast and cheap source of power generation? Nuclear power is not sufficient because nuclear fuel reserves are limited (Kasting, 1998). Radioactive waste disposal is still an unsolved problem. Breeder reactors are much riskier and more costly. The problem is that alternative sources, including solar and conservation, will do no good unless these sources *replace*, not augment, fossil fuels. Offsetting emissions through re-forestation can have only a negligible effect (Kasting, 1998). Stabilizing the global climate at levels at 2–3 °C above current temperatures will require phasing out fossil fuel use, especially coal. According to Socolow et al. (2004), to keep atmospheric CO₂ at double its pre-industrial level, emissions should be kept under the current level of 7 gigatons until 2054, then rapidly decline after that. If climate stability is the goal, the use of coal as an energy source needs to be rapidly curtailed.⁸

Most economists dealing with climate change focus on the “rational allocation” problem, that is, finding the most efficient way to allocate a given level of carbon emissions. Economists have had relatively little to say about how to design policies that would enhance international cooperation or about the economic implications of massively substituting non-carbon

⁷ During the Late Pleistocene Thermal Maximum the earth's average temperature rose by about 7 °C. This sudden temperature rise lasted for about 150,000 years and was triggered by a massive release of methane from the ocean floor (NASA News Archive, December 10, 2001).

⁸ Realistically, it must be admitted that the prospects of doing this are bleak. With China and India industrializing, coal use and carbon emissions are rising faster than ever. Annual carbon emission grew by about 0.8 percent from 1990 to 1999. From 2000 to 2005 they grew by 3.2 percent or four times faster (Brahic, 2006). China has plans to build 562 coal-fired power plants in the next 8 years, India plans to build 213, and the U.S., 72 (Clayton, 2004).

fuels.⁹ Again, the problem is how to reduce sharply, then eliminate, CO₂ emissions, not how to theoretically allocate some given amount of carbon (Socolow, 2005). Moving away from a fossil fuel economy requires institutional change, not merely modifying individual behavior at the margin. The climate change problem arose from the patterns of behavior that developed as a direct result of cheap energy and the consumer society that grew out this productivity bonanza. Can behavioral science offer clues as to how those patterns of behavior, and the institutions that reinforce them, might be modified?

5. Can behavioral science inform climate change policies?

The robustness of the findings from behavioral economics led to a growing recognition that the model of extreme rationality is of limited value as a predictor of human behavior in complex social situations (Camerer et al., 2005; Rieskamp et al., 2006). The time seems ripe to replace the rational actor assumptions underlying current public policy with ones that incorporate the regularities of human behavior uncovered by behavioral science. Work along this line is being done by psychologists (Amir et al., 2005; Milinski et al., 2006) but has been met with resistance by economists (see Kahneman, 2003, Section 4).¹⁰ How can global warming policies be designed based on behavioral science?

5.1. Optimization based on rational choice is an inadequate analytical framework

The Walrasian core of economic theory gives little guidance as to how to limit fossil fuel use except on the basis of preferences as expressed in markets or quasi-market situations (Gowdy, 2004a,b). If preferences are considered to be "givens" then today's consumption may trump avoiding substantial climate change in the future. The reasoning is something like "People living in the present may value a stable climate in the future but they value today's lavish vacations, larger houses and bigger SUVs more." The goal of Walrasian policy, based on the first two fundamental theorems of welfare economics, is to adjust prices (and perhaps distribution through lump sum transfers) to create the conditions for competitive equilibrium. Correcting a specific problem is not the ultimate focus of standard economic analysis. The policy focus is on designing allocation frameworks based on the duck/pigeon model of human behavior assuming that the optimal social outcome is achieved by rational agents responding mechanically to price signals. In this framework, prices are the incentive for achieving social responsibility. In Walrasian models of sustainability, the only policy "decision" is to choose the social rate of discount (see for example the criticisms of the Stern Report by Dasgupta, 2006; Nordhaus, 2007 and others).

But global warming is a physical problem involving the interaction between physical economic production and the physical characteristics of the atmosphere. Adjusting prices based on carbon taxes or cap-and-trade programs to optimally allocate a given reduction is really a secondary problem. This is not to say that these policies cannot be valuable, but economists should have more to say about public policy than assigning property rights and adjusting relative prices. The generalized Darwinism approach to policy recognizes that macro outcomes are the result of the action of individuals responding to behavioral incentives, but it also recognizes that incentives include more than prices, that they are embedded in cultural institutions, and that a broadly defined incentive structure should be part of public policy.

5.1.1. Beyond monetary incentives

The body of evidence discussed earlier indicates that financial incentives can actually crowd out feelings of civic responsibility (Frey) and may actually discourage the kinds of behaviors needed to solve collective social problems such as global climate change. Almost all environmental problems involve some notion of the common good. Behavioral experiments show that the social good can be undermined by the mere mention of money. In contrast to the policy recommendations of most economists, relying on monetary incentives to tackle collective choice problems can have perverse effects. As environmental philosophers have argued (O'Neill, 1993; Norton, 2005) giving people a shared responsibility and appealing directly to a sense of the common good can be an effective way of gaining acceptance for environmental policies.

5.1.2. Is materialistic behavior "natural"?

During the past 100 years or so, consumerism and materialism came to be the dominant form of behavior in industrial market societies and this behavioral pattern is rapidly sweeping over the entire planet. But this behavior is no more "natural" than any other of the thousands of behavioral patterns exhibited in human cultures throughout our history (Sahlins, 1996). Like other cultural patterns, consumerism is dominant not because of genes but rather because of cultural systems of rewards and punishments. Citizens of industrial societies are subjected to hundreds of commercial messages daily. These messages not only promote specific products, but they also promote a lifestyle based on material consumption. The emerging economies of China and India also seem to be locked into the model of social status through conspicuous consumption. Prospects

⁹ For critiques of economic models of climate change see Gowdy (2004b), Hall and Behl (2006), Laitner et al. (2001), Spash (2002) and Van den Bergh (2004).

¹⁰ Economists using evidence from behavioral economics to suggest a redirection of public policy include Layard (2005), Frey and Stutzer (2002), Kahneman and Sugden (2005), Ng (1987, 1997) and Frank (1999). Very practical examples of using behavioral understandings to inform policy include the design of savings plans (Bernartzi and Thaler, 2004), encouraging fertilizer adoption in Kenya (Duflo et al., 2005), and improving the reliability of identifications in police lineups (Wells et al., 2000).

for changing this behavior may seem bleak but it is important to remember the malleability of human culture. It is easy to imagine new ways of living with different systems of rewards and punishment promoting more environmentally (and socially) benign ways of status seeking.

5.1.3. Discounting the future

Traditionally, economic models involving intergenerational welfare discount the future using a constant (straight-line) discount rate. [Nordhaus and Yang \(1996, p. 755\)](#), for example use a constant discount rate on consumption of 4 1/2 percent per year. [Stern \(2007\)](#) uses a 0.1 percent rate throughout, reflecting only the small probability that some catastrophic event will decimate the human species during the time period in question,¹¹ but behavioral studies have shown that people have higher internal discounts over short time horizons and lower ones over the medium to distant future, so-called hyperbolic discounting ([Karp, 2004](#); [Laibson, 1997](#)). There is an interesting parallel between the behavioral studies and the recommendations of many economists regarding the valuation of long-term resource use decisions. [Beltratti et al. \(1998\)](#) advocate the use of the “green golden rule” for renewable resources, using something near market discount rates in the short run (so that the present is not exploited) and a rate asymptotically approaching zero in the long run (so that the future is not exploited). Similarly, [Weitzman \(2001\)](#) advocates what he terms “gamma discounting” using a rate of about 4 percent for the immediate future with a steady decline to near zero in the distant future. An awareness of hyperbolic discounting has successfully informed policy regarding pension savings plans ([Bernartzi and Thaler, 2004](#)).¹²

5.1.4. Tipping points and threshold effects

As discussed earlier threshold effects have been identified in the brain activity of individual animals making motor decisions. Threshold effects have also been identified in collective decision-making in social animals. For example, spinner dolphins spend most of their time either feeding or sleeping in a protected area, behind a coral reef for example. The decision to quit sleeping and leave the protected area to feed is apparently collectively made based on a kind of “consensus threshold.” When they begin to wake up, the dolphins use zigzag swimming motions to cast their “votes” for sleeping or feeding. When a threshold is reached the dolphins as a group leave the safe area and go to feed in the danger of the deep ocean ([Whitty, 2006](#), 40). This kind of group coordination, with different kinds of threshold consensus, is common among social animals from crows to chimpanzees to bison. Group consensus was apparently how important decisions were made in human groups prior to agriculture, judging from historical accounts of hunter-gatherers (see the essays in [Gowdy, 1998](#)).

The climate change challenge is unique compared to other public choice challenges since it involves changing the organizing principle of the industrial economy: abundant and cheap energy. Changing this well-established and highly successful (from a strictly material point of view) pattern of production and consumption presents many dilemmas intertwining social justice, technology, and behavior ([Paavola and Adger, 2006](#)). Avoiding dangerous climate change will require lifestyle changes and cross-cultural cooperation on an unprecedented scale. Is there a threshold, or tipping point, that would trigger the consensus and political will to attack the causes of climate change seriously? Only time will tell, but it seems prudent for economists to be ready with appropriate policies to encourage cooperative solutions when or if such a tipping point occurs.

The behavioral model of rational economic man has dominated economic theory and policy for 100 years or more. Behavioral economics has come of age only in the last decade or so, and it is too early to expect a full-blown policy agenda from it. However, broad and general patterns of behavior have been identified, and these patterns offer clues for global warming policy.

5.2. Policy Clue 1: increased consumption does not necessarily translate into increased well-being

Climate change is driven by increasing fossil fuel consumption used to produce an ever larger amount of consumer goods. Numerous studies have demonstrated that, past a certain point, increasing per capita income does not increase well-being. The implication is that slowing or halting per capita income growth need not reduce social welfare. This is a very important starting point since the drastic reduction in fossil fuel use required to stabilize the climate will certainly mean a reduction in the production of consumer goods. A number of economists call for a re-orientation of welfare policy goals from “income” to “well-being” ([Frey and Stutzer, 2002](#); [Kahneman and Sugden, 2005](#); [Layard, 2005](#)). The assumptions of the rational actor model (including “more is preferred to less”) force a trade-off between material consumption and environmental protection. Evidence suggests that this is a gross oversimplification.

¹¹ The problem with standard economic analyses of climate change, including the Stern report, is not so much the choice of a discount rate but rather the assumptions that (1) well-being is equivalent to per capita income and (2) future income will continue to grow exponentially. Within this framework Nordhaus is justified in asking why the current generation with a worldwide annual per capita income of \$10,000 should sacrifice to eliminate relatively small income losses for those making \$130,000 in the year 2100. But do Nordhaus's and Stern's income projections have any credibility? Too much attention is being focused on the discount rate choice and too little on the validity of the numbers being discounted.

¹² Telling criticisms of using a social discount rate (discounted utility) for public policy have been made by [Frederick et al. \(2002\)](#) and [Rubinstein \(2003\)](#).

5.3. Policy Sub-Clue 1a: absolute income may not be strongly correlated with well-being but relative income is

People are very concerned about their relative position in society, and this concern may drive patterns of consumption (Frank, 1999; Veblen, 1898). This implies that policies to reduce consumption must be carefully formulated to minimize redistribution effects. This need not mean an order-preserving reduction in income, but the relative losers in consumption reduction should be compensated in some way that minimizes their relative income loss. The wealthy for example, could be rewarded with some sort of public recognition of their sacrifice for the common good. People are more inclined to give to public goods when they can be observed to do so, and this could be incorporated into climate change policy.

Howarth (2006) explores how the presence of relative consumption effects might inform environmental tax policy. Accounting for such effects reduces the value of individual consumption and increases the willingness to pay for public goods such as environmental amenities. In terms of implementing this policy, a problem is the time lag between having your income decreased through a tax and realizing much later that your income relative to others is unchanged.

5.4. Policy Sub-Clue 1b: development in poorer countries need not focus exclusively on increasing per capita consumption

“Development” in the third world need not follow the path of the industrialized nations during the twentieth century. Sen (1999) has called for an approach to development emphasizing the ability to live an informed and full life rather than concentrating solely on income creation. Nussbaum (2000, chapter 4 and website of Human Development and Capabilities Association) has gone further in calling for “distributive justice”, that is, creating the conditions for the realization of a set of central human capabilities. Such policies would not only be more effective than simple income growth in making lives better for the world’s poorest, but they would also help to alleviate the pressure on the environment from more economic production. With a focus on individual happiness and self-actualization, the developing world could improve its position relative to the North without emulating the consumption frenzy that drove past economic growth.

China may be a case in point. Real income per capita in China increased by a factor of 2.5 between 1994 and 2005. Material well-being increased substantially (for example, ownership of color TVs rose from 40 percent to 82 percent of households) but according to a Gallop survey of 15,000 individuals, the percentage of people who reported being “dissatisfied with the way things are going in your life” rose from 20 percent to 35 percent, and the number who reported being satisfied fell from 80 percent to 65 percent (see the discussion in Kahneman and Krueger, 2006).

5.5. Policy Clue 2: the ability to cooperate with unrelated others is an almost unique characteristic of the human species

Humans and other closely related primates cooperate on a scale not present in any other mammalian species. Recent evidence indicates that this cooperation goes beyond traditional explanations based on kinship and tit-for-tat reciprocity (De Waal, 1996; Field, 2001; Sober and Wilson, 1998; Vogel, 2004). For most of our existence as a species we lived in small groups in environments where cooperation was essential for survival. Groups of people who cooperated were able to out-compete those who did not (Gowdy and Seidl, 2004; Sober and Wilson, 1998). Successfully dealing with global climate may require cooperation on an unprecedented scale among people with radically different values and radically different needs. This brings up the importance of evolved trust in developing cooperative institutions (Rosser and Rosser, 2006). Even when cooperative frameworks are imperfect (the Kyoto agreement, for example), it can be important to participate in them to establish credibility and good will.

There is, of course, a huge difference between cooperating on small versus very large scales. Schelling (2002) discusses the difficulty of international cooperation but points to the success of the Marshall Plan immediately after WWII and NATO in the 1950s. Both of these involved massive income transfers among countries to achieve a common goal (economic recovery and international security). As Schelling points out, in these cases, commitments were made to taking certain actions but not, as in the case of the Kyoto accord, to specific measurable results. The policy advantage is that actions are immediately observable while distant targets are not.

5.6. Policy Sub-Clue 2a: cooperation depends on the ability to punish free-riders

Boyd and Richerson (1992) make a strong case that almost any type of human behavior can be called forth through social punishment mechanisms. Henrich (2006) argues further that cooperation and punishment go hand in hand. People are willing to make sacrifices for others when they are assured that others (free riders) can be punished if they take advantage of altruistic behavior. Henrich et al. (2006) present cross-cultural results from 15 diverse populations indicating (1) all populations showed a willingness to punish free riders, (2) the amount of punishment varied considerably across the groups studied, and (3) costly punishment was positively correlated with altruistic behavior. These findings and other game theoretic experiments are valuable in informing climate change policy.

Stiglitz (2006) calls for using the international trade framework to impose penalties on countries (such as the U.S. under the Bush administration) that refuse to cooperate in reducing CO₂ emissions. He suggests that Japan, Europe, and other signatories of the Kyoto agreement should bring a WTO case against the U.S. for unfair trade subsidization arising from U.S. energy and environmental policies. “With a strong international sanction mechanism in place, all could rest assured that there was, at last, a level playing field” (Stiglitz, p. 2–3).

5.7. Policy Sub-Clue 2b: climate change policies will not work unless they are perceived as being fair

A major issue in global climate change policy is the fairness of the policy with respect to developing countries. The earth is approaching a tipping point in global climate change because the industrialized world has pushed CO₂ levels from 280 ppm to 380 ppm in the last hundred years. The North has gotten rich by burning fossil fuels, and now we are telling the poor countries to stop this practice. Stiglitz suggests that a fair way out of this dilemma is a common (global) carbon tax on emissions. He suggests that the tax revenue be kept by each individual country and used to reduce taxes on capital and labor. Kahn and Franceschi (2006) present a detailed proposal for such a tax that emphasizes fairness as well as efficiency. The revenues from such a tax could be placed in a common pool that could be used for such things as education, health, and alternative energy projects. Most of this money could go to the world's poor countries both in the interest of fairness and the practical need for these countries to avoid the path of energy extravagance followed by the North.

Frey argues that monetary incentives can crowd out civic motives, but he also acknowledges that money can "crowd in" civic motivations when it is used to acknowledge the social worth of individuals' contributions. This is relevant to channeling financial aid to ease the climate change burden on the developing world. Monetary compensation and technology transfers to the developing world would represent an acknowledgement of the responsibility of the developed world for driving up CO₂ levels during the past 100 years.

5.8. Policy Sub-Clue 2c: global cooperation on climate change policy can draw upon our ability to cooperate as well as our ability to compete

For most of our existence as a species humans lived in small groups within the confines of local ecosystems. According to some (Boehm, 1997) cooperation evolved because those groups that worked together survived while those that did not perished. Institutional rules for cooperation and living within biophysical limits emerged in pre-agricultural human societies to insure the sustainability of these small groups. The rules of the game changed with the widespread adoption of agriculture some 10,000 years ago as we broke out of the confines of local ecosystems. Today we once again find ourselves up against the confines of a natural system, this time the global system 'Gaia' (Eldredge, 1995). Responding to the climate change threat depends on returning to the level of human cooperation that prevailed in pre-industrial societies.

Humans may be unique among mammals in the extent of their cooperation with others, but it is also true that humans are almost unique in the extent to which they are willing to annihilate members of their own species that do not belong to the "in" group. Experiments and observation show that people are more willing to cooperate with "like" others than with outgroup persons. The task of climate change policy is to make our entire species the "in" group. This was Georgescu-Roegen's admonishment for sustainable behavior: "Love thy species as thyself."

6. Conclusion

The current crisis of sustainability cannot be resolved within the confines of the system that generated it. For economic analysis this means stepping outside the Walrasian system with its emphasis on one part of human nature (greed and egoism) to the neglect of other the facets of human nature (cooperation and altruism). The marginal approach of traditional economic analysis, with its near exclusive emphasis on optimal allocation through prices and property rights, is not up the task of describing real human behavior and the structure of economic institutions. This is critically important at this stage in the development of economic thought. The mechanistic worldview has collapsed, evolutionary biology has replaced physics as the field of inspiration for the philosophy of science, and the unification of the social sciences is well underway.

For social policy, leaving the confines of the current system means drawing upon aspects of human nature emphasizing cooperation, non-materialistic values, and a shared sense of urgency. Given the overwhelming dominance of the consumption-as-happiness ethic in our culture, the task of finding a less materialistic path seems daunting, but greed and accumulation are only a part of the richness of human behavioral patterns. These have come to prominence because they have been rewarded through an incentive structure that grew hand in hand with the production bonanza made possible by cheap and abundant fossil fuels. Types of behavior conducive to cooperation, doing with fewer material possessions, and recognizing the necessity of shared sacrifice are also part of the human experience.

Global climate change is perhaps the most serious threat faced by modern humans. Even stabilizing future warming of the earth at 2–3 °C above its present temperature will require monumental efforts (Lenton et al., 2006; Socolow, 2005). In fact, the task of meeting the climate change challenge may prove to be impossible. But behavioral science at least offers a more far-reaching and realistic approach to designing policies that might get us through this impending crisis.

Acknowledgements

The author would like to thank the following people for comments on an earlier draft: David George, Gregory Graff, James Kasting, Carl McDaniel, Mikko Manner, Julie Nelson, Richard Norgaard, Jouni Paavola, Inge Røpke, Richard Rosen, Barkley Rosser, Clive Spash, Martha Starr, and Marsha Walton.

References

Amir, O., Ariely, D., Cooke, A., Dunning, D., Epley, N., Gneezy, U., Koszegi, B., Lichtenstein, D., Mazar, N., Mullainathan, S., Prelec, D., Shafir, E., Silva, J., 2005. Psychology, behavioral economics, and public policy. *Marketing Letters* 16, 443–454.

Arkes, H., Ayton, P., 1999. The sunk cost and concorde effects: are humans less rational than lower animals? *Psychological Bulletin* 125, 591–600.

Bala, G., Caldeira, K., Mirin, A., Wickett, M., Delire, C., 2005. Multicentury changes in global climate and carbon cycle: results from a coupled climate and carbon cycle model. *Journal of Climate* 18, 4531–4544.

Beltratti, A., Chichilnisky, G., Heal, G., 1998. Sustainable use of renewable resources. In: Beltratti, A., Chichilnisky, G., Heal, G. (Eds.), *Sustainability: Dynamics and Uncertainty*. Kluwer, Dordrecht, pp. 49–76.

Bernartzi, S., Thaler, R., 2004. Save more tomorrow: using behavioral economics to increase employee savings. *Journal of Political Economy* 112, 164–187.

Boehm, C., 1997. Impact of the human egalitarian syndrome on Darwinian selection mechanics. *The American Naturalist* 150 (Suppl.), S100–S121.

Boyd, R., Richerson, P., 1992. Punishment allows the evolution of cooperation (or anything else) in sizable groups. *Journal of Ethology and Sociobiology* 13, 171–195.

Brahic, C., 2006. Carbon emissions rising faster than ever. *NewScientist.com News Service*, November 10. <http://environment.newscientist.com/channel/earth/dn10507-carbon-emissions-rising-faster-than-ever.html>.

Bromley, D., 2006. *Sufficient Reason*. Princeton University Press, Princeton and Oxford.

Brosnan, S., de Wall, F., 2003. Monkeys reject unequal pay. *Nature* 425, 297–299.

Caldeira, K., Kasting, J., 1993. In sensitivity of global warming potentials to carbon dioxide emission scenarios. *Nature* 366, 251–253.

Camerer, C., Loewenstein, G., Rabin, M. (Eds.), 2004. *Advances in Behavioral Economics*. Princeton University Press, Princeton and Oxford.

Camerer, C., Loewenstein, G., Prelec, D., 2005. Neuroeconomics: how neuroscience can inform economics. *Journal of Economic Literature* 43, 9–64.

Clayton, M., 2004. New coal plants bury 'Kyoto'. *The Christian Science Monitor*, December 23. <http://www.csmonitor.com/2004/1223/p01s04-sten.html>.

Dasgupta, P., 2006. Comments on the Stern Review's economics of climate change. In: *Foundation for Science and Technology*. Royal Society of London, November 11.

De Martino, B., Kumaran, D., Seymour, B., Dolan, R., 2006. Frames, biases, and rational decision-making in the human brain. *Science* 313, 684–687.

De Waal, F., 1996. *Good Natured: The Origins of Right and Wrong in Humans and Other Animals*. Harvard University Press, Cambridge and London.

Dow, K., Downing, T., 2006. *The Atlas of Climate Change*. Earthscan, Brighton, UK.

Duflo, E., Kremer, M., Robinson, J., 2005. Understanding technology adoption: Fertilizer in Western Kenya, preliminary results from field experiments. Working paper MIT.

Eldredge, N., 1995. *Dominion*. University of California Press, Berkeley.

Fantino, E., 2004. Behavior-analytic approaches to decision making. *Behavioral Processes* 66, 279–288.

Field, A., 2001. *Altruistically Inclined?* University of Michigan Press, Ann Arbor.

Flannery, T., 2005. *The Weather Makers*. Atlantic Monthly Press, New York.

Frank, R., 1999. *Luxury Fever: Why Money Fails to Satisfy in an Age of Excess*. Free Press, New York.

Frank, R., Bernanke, B., 2004. *Principles of Economics*, 2nd edition. McGraw-Hill, New York.

Frederick, S., Loewenstein, G., O'Donoghue, T., 2002. Time discounting and time preference: a critical review. *Journal of Economic Literature* 40, 351–401.

Frey, B., 1997. A constitution of knaves crowds out civic virtues. *Economic Journal* 107, 1043–1053.

Frey, B., Oberholzer-Gee, F., 1997. The cost of price incentives: an empirical analysis of motivation crowding out. *American Economic Review* 87, 746–755.

Frey, B., Stutzer, A., 2002. *Happiness and Economics: How the Economy and Institutions Affect Well-being*. Princeton University Press, Princeton and Oxford.

Gintis, H., 2000. Beyond *Homo economicus*: evidence from experimental economics. *Ecological Economics* 35, 311–322.

Gintis, H., 2006. Cultural Darwinism. *Boston Review*. <http://bostonreview.net/BR23.1/Gintis/html>.

Gintis, H., 2007. A framework for the integration of the behavioral sciences. *Behavioral and Brain Sciences* 30, 1–16.

Glimcher, P., 2002. Decisions, decisions, decisions: choosing a biological science of choice. *Neuron* 36, 323–332.

Glimcher, P., Dorris, M., Bayer, H., 2005. Physiological utility theory and the neuroeconomics of choice. *Games and Economic Behavior* 52, 213–256.

Gowdy, J., 1998. *Limited Wants, Infinite Means: A Reader on Hunter-Gatherer Economics and the Environment*. Island Press, Washington, DC.

Gowdy, J., 2004a. Altruism, evolution, and welfare economics. *The Journal of Economic Behavior and Organization* 53, 69–73.

Gowdy, J., 2004b. The revolution in welfare economics and its implications for environmental valuation and policy. *Land Economics* 80, 239–257.

Gowdy, J., Seidl, I., 2004. Economic man and selfish genes: The relevance of group selection to economic policy. *Journal of Socio-Economics* 33, 343–358.

Gowdy, J., Iorgulescu, R., Onyeiwu, S., 2003. Fairness and retaliation in a rural Nigerian village. *Journal of Economic Behavior and Organization* 52, 469–479.

Güth, W., Schmittberger, R., Schwarz, B., 1982. An experimental analysis of ultimatum game bargaining. *Journal of Economic Behavior and Organization* 3, 367–388.

Hall, D., Behl, R., 2006. Integrating economic analysis and the science of climate instability. *Ecological Economics* 57, 442–465.

Hardin, G., 1968. The tragedy of the commons. *Science* 162, 1243–1248.

Harper, D., 1982. Competitive foraging in mallards: "ideal free" ducks. *Animal Behavior* 30, 575–584.

Henrich, J., 2006. Cooperation, punishment, and the evolution of human societies. *Science* 312, 60–61.

Henrich, J., Boyd, R., Bowles, S., Camerer, C., Fehr, E., Gintis, H., McElreath, R., 2001. In search of *Homo economicus*: behavioral experiments in 15 small-scale societies. *American Economic Review* 91, 73–78.

Henrich, J., McElreath, R., Barr, A., Ensminger, J., Barrett, C., Bolanyatz, A., Cardenas, J., Gurven, M., Gwako, E., Henrich, N., Lesorogol, C., Marlowe, F., Tracer, D., Ziker, J., 2006. Costly punishment across human societies. *Science* 312, 1767–1770.

Hodgson, G., 2004. *The Evolution of Institutional Economics*. Routledge, London and New York.

Howarth, R., 2006. Optimal environmental taxes under relative consumption effects. *Ecological Economics* 58, 209–219.

Howarth, R., Wilson, M., 2006. A theoretical approach to deliberative valuation. *Land Economics* 82, 1–16.

Intergovernmental Panel on Climate Change. *Climate Change 2007—The Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC*. www.ipcc.ch.

Kahn, J., Franceschi, D., 2006. Beyond Kyoto: a tax-based system for the global reduction of greenhouse gas emissions. *Ecological Economics* 58, 778–787.

Kahneman, D., 2003. A psychological perspective on economics. *American Economic Review* 93, 162–168.

Kahneman, D., Krueger, A., 2006. Developments in the measurement of subjective well-being. *Journal of Economic Perspectives* 20 (1), 3–24.

Kahneman, D., Tversky, A., 1979. Prospect theory: an analysis of decision under risk. *Econometrica* 47, 263–291.

Kahneman, D., Sugden, R., 2005. Experienced utility as a standard of policy evaluation. *Environmental and Resource Economics* 32, 161–181.

Karp, L., 2004. Global warming and hyperbolic discounting. *CUDARE Working Paper 934R*, Department of Agricultural and Resource Economics, University of California, Berkeley.

Kasting, J., 1998. The carbon cycle, climate, and the long-term effects of fossil fuel burning. *Consequences* 4, 15–27.

Kump, L., 2002. Reducing uncertainty about carbon dioxide as a climate driver. *Nature* 419, 188–190.

Laibson, D., 1997. Golden eggs and hyperbolic discounting. *Quarterly Journal of Economics* 112, 443–477.

Laitner, J., DeCanio, S., Peters, I., 2001. Incorporating behavioral, social, and organizational phenomena in the assessment of climate change mitigation options. In: Jochum, E., Sathaye, J., Bouille, D. (Eds.), *Society, Behavior, and Climate Change Mitigation*. Kluwer, Dordrecht, pp. 1–65.

Layard, R., 2005. *Happiness: Lessons from a New Science*. Penguin Press, New York.

Lenton, T., Loute, M.-R., Williamson, M., Warren, R., Goodess, C., Swann, M., Cameron, D., Hankn, R., Marsh, R., Shephard, J., 2006. *Climate Change on the Millennial Timescale*. Tydall Centre for Climate Change Research, Technical Report 41.

Loewenstein, G., 2004. Out of control: visceral influences on behavior. In: Camerer, C., Loewenstein, G., Rabin, M. (Eds.), *Advances in Behavioral Economics*. Princeton University Press, Princeton and London, pp. 689–724.

McCauley, D., 2006. Selling out on nature. *Nature* 443, 27–29.

Maestripieri, D., Alleva, E., 1991. Litter defense and parental investment allocation in house mice. *Behavioral Processes* 56, 223–230.

Melis, A., Hare, B., Tomasello, M., 2006. Chimpanzees recruit the best collaborators. *Science* 311, 1297–1300.

Milinski, M., Semmann, D., Krambeck, H.-J., Marotzke, J., 2006. Stabilizing the earth's climate is not a losing game: supporting evidence from public goods experiments. *Proceedings of the National Academy of Sciences* 103, 3994–3998.

Miller, G., 2006. The emotional brain weighs its options. *Science* 313, 600–601.

NASA News Archive. 2001. Methane explosion warmed the prehistoric earth, possible again (December). <http://earthobservatory.nasa.gov/Newsroom/NasaNews/2001/200112.html>.

Nelson, J., 2005. Is economics a natural science? *Cosmos and History: The Journal of Natural and Social Philosophy* 2, 261–269.

Ng, Y.-K., 1987. Diamonds are a government's best friend: burden-free taxes on goods valued for their values. *American Economic Review* 77, 186–191.

Ng, Y.-K., 1997. A case for happiness, cardinalism, and interpersonal comparability. *Economic Journal* 107, 1848–1858.

Nordhaus, W., 2007. The *Stern Review* on the economics of climate change. *Journal of Economic Literature* XLV, 686–702.

Nordhaus, W., Yang, Z., 1996. A regional dynamic general equilibrium model of alternative climate-change strategies. *American Economic Review* 86, 741–765.

Norgaard, R., 1989. The case for methodological pluralism. *Ecological Economics* 1, 37–58.

Norgaard, R., 2006. Deliberative Economics. In: Kenneth Boulding Memorial Lecture, International Society for Ecological Economics, Delhi, India, December 13.

Norton, B., 2005. *Sustainability: A Philosophy of Adaptive Ecosystem Management*. University of Chicago Press, Chicago.

Nowak, M., Page, K., Sigmund, K., 2000. Fairness versus reason in the ultimatum game. *Science* 289, 1773–1775.

Nussbaum, M., 2000. *Women and Human Development*. University of Chicago Press, Chicago.

O'Neill, J., 1993. *Ecology, Policy and Politics: Human Well-Being and the Natural*. Routledge, London.

O'Neill, J., Spash, C., 2000. Conceptions of value in environmental decision-making. *Environmental Values* 9, 521–535.

Paavola, J., Adler, W., 2006. Fair adaptation to climate change. *Ecological Economics* 56, 594–609.

Pesendorfer, W., 2006. Behavioral economics comes of age: a review essay on Advances in Behavioral Economics. *Journal of Economic Literature* 44, 712–721.

Richerson, P., Boyd, R., 2005. *Not by Genes Alone*. University of Chicago Press, Chicago.

Rieskamp, J., Busemeyer, J., Mellers, B., 2006. Extending the bounds of rationality: evidence and theories of preferential choice. *Journal of Economic Literature* 44, 631–661.

Rosser, B., Rosser, M., 2006. Institutional evolution of environmental management under global economic growth. *Journal of Economic Issues* 45, 421–429.

Rubinstein, A., 2003. Economics and Psychology: the case of hyperbolic discounting. *International Economic Review* 44, 1207–1216.

Sagoff, M., 1988. *The Economy of the Earth*. University of Chicago Press, Chicago.

Sahlins, M., 1996. The sadness of sweetness: a native anthropology of Western cosmology. *Current Anthropology* 37, 395–428.

Schall, J., Thompson, K., 1999. Neural selection and control of visually guided eye movements. *Annual Review of Neuroscience* 22, 241–259.

Schultz, W., 2002. Getting formal with dopamine and reward. *Neuron* 36, 241–263.

Schultz, W., Dayan, P., Montague, P., 1997. A neural substrate of prediction and reward. *Science* 275, 1593–1599.

Searle, J., 2001. *Rationality in Action*. MIT Press, Cambridge and London.

Sen, A., 1999. *Development as Freedom*. Anchor Books, New York.

Schelling, T., 2002. What makes greenhouse sense? *Foreign Affairs* 81, 2–8.

Sober, E., Wilson, D., 1998. *The Evolution and Psychology of Unselfish Behavior*. Harvard University Press, Cambridge and London.

Socolow, R., 2005. Can we bury global warming? *Scientific American* 293, 49–55.

Socolow, R., Hotinski, R., Greenblatt, J., Pacala, S., 2004. Solving the climate problem. *Environment* 46, 8–19.

Spash, C., 2002. *Greenhouse Economics*. Routledge, London and New York.

Stern, N., 2007. *The Economics of Climate Change: The Stern Review*. Cambridge University Press, Cambridge, UK.

Stiglitz, J., 2006. A New Agenda for Global Warming. *Economists' Voice*, July. www.bepress.com/ev.

Titmuss, R., 1971. *The Gift Relationship: From Human Blood to Social Policy*. Pantheon Books, New York.

Tom, S., Fox, R., Trepel, C., Poldrack, R., 2007. The neural basis of loss aversion in decision-making under risk. *Science* 315, 515–518.

Van den Bergh, J., 2004. Optimal climate policy is a utopia: from quantitative to qualitative cost-benefit analysis. *Ecological Economics* 48, 385–393.

Veblen, T., 1898. Why is economics not an evolutionary science? *Quarterly Journal of Economics* 12, 373–397.

Vogel, G., 2004. The evolution of the golden rule. *Science* 303, 1128–1131.

Vohs, K., Mead, N., Goode, M., 2006. The psychological consequences of money. *Science* 314, 1154–1156.

Weitzman, M., 2001. Gamma discounting. *American Economic Review* 91, 260–271.

Wells, G., Malpass, R., Linsey, R., Fisher, R., Turtle, W., Fulero, S., 2000. From the lab to the police station: a successful application of eyewitness research. *American Psychologist* 55, 581–598.

Whitty, J., 2006. The 13th tipping point. *Mother Jones*, November/December, 45–51, 100. <http://www.motherjones.com/news/feature/2006/11/13th.tipping.point.html>.

Whyte, G., 1993. Escalating commitment in individual and group decision making: a prospect theory approach. *Organizational Behavior and Human Decision Processes* 54, 430–455.