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Department of Economics, Rensselaer Polytechnic Institute, 110 8th Street, Troy, NY, 12180-3590, USA. Tel: +1-518-276-6387; Fax: +1-518-276-2235; URL: http://www.rpi.edu/dept/economics/; E-Mail: sternd@rpi.edu

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John M. Gowdy
Rensselaer Polytechnic Institute

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John M. Gowdy
Rittenhouse Teaching Professor of Humanities and Social Science
Department of Economics
Rensselaer Polytechnic Institute
Troy, New York 12180-3590
gowdyj@rpi.edu

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ABSTRACT

The policy recommendations of most economists are based, explicitly or implicitly, on the *rational actor* model of human behavior. Behavior is assumed to be self-regarding, preferences are assumed to be stable, and decisions are assumed to be unaffected by social context or frame of reference. The related fields of behavioral economics, game theory, and neuroscience have confirmed that human behavior is other regarding, and that people exhibit systematic patterns of decision-making that are "irrational" according to the standard behavioral model. This paper takes the position that these "irrational" patterns of behavior are central to human decision making and therefore, for economic policies to be effective these behaviors should be the starting point. This contention is supported by game theory experiments involving humans, closely related primates, and other animals with more limited cognitive ability.

The policy focus of the paper is global climate change. The research surveyed in this paper suggests that the standard economic approach to climate change policy, with its almost exclusive emphasis on rational responses to monetary incentives, is seriously flawed. In fact, monetary incentives may actually be counter-productive. Humans are unique among animal species in their ability to cooperate across cultures, geographical space and generations. Tapping into this uniquely human attribute, and understanding how cooperation is enforced, holds the key to limiting the potentially calamitous effects of global climate change.

JEL Codes: C7, D6, D7, D8, Q2

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BEHAVIORAL ECONOMICS AND CLIMATE CHANGE POLICY

I. Introduction

Behavioral research has fundamentally changed the field of economics by putting it on an experimental basis (Camerer, Loewenstein, and Rabin, 2004; Gintis, 2006a). 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 actor[1] 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 revealed 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 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 it is a unified, highly evolved system with complementary, rather than conflicting, components (Glimcher, Dorris and Bayer 2005). Furthermore, it is the "anomalies"—the deviations from the rational actor model—that make humans almost unique in the animal kingdom. 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 unified[3] 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, one of the greatest challenges our species faces, is used as an example of how sustainability policies might be informed by contemporary theories of human choice.

II. New insights into human behavior

One of the most important contributions to behavioral economics was the Ultimatum Game[4] (UG) formulated twenty-five years ago by Güth, Schmittberger, and

Schwarz (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 of great relevance 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, have a sense of fairness and a tendency to cooperate, even at a cost to themselves. Secondly, "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.

The behavior of social animals

Melis, Hare, and Tomasello (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 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. The authors observe: "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" (Melis, Hare, and Tomasello 2006, 1297). Kin selection is not involved since the chimpanzees at the sanctuary are unrelated orphans from the wild.

Economists tend to be skeptical of altruistic behavior because such 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, 1767) argue that altruism arose in humans hand-in-hand with punishment. Altruistic punishment, or 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, 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 optimality 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)

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 gram dough balls at different intervals. Expected utility theory would predict that the ducks would distribute themselves between the two feeders in such as 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. So if there are 33 ducks participating and if one experimenter throws a 5 gram ball of dough every 15 seconds and the other experimenter throws a 5 gram ball of dough every 30 seconds, there should be 22 ducks in front of the first experimenter and 11 in front of the other. And 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 correctly readjust their numbers with about 90 seconds. Glimscher (2002, 329) writes:

> One thing that was particularly striking about this result was the speed at which the ducks achieved this assortment. After 90 seconds 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 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. 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 they 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, 2003).

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 Oberholtzer-Gee 2002). A classic example is the result that paying blood donors significantly reduces blood donations (Titmus 1971). A recent experiment found that the mere mention of "money" had a negative effect on sociality. Vohs, Mead and Goode (2006) performed several experiments which compared various kinds of social behavior in groups of people that 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 which 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:

> The results of nine experiments suggest that money brings about a self-sufficient orientation in which people prefer to be free of dependency and dependents. Reminders of money, relative to nonmoney reminders, led to reduced requests for help and reduced helpfulness toward others. 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." (Vohs, Mead, and Goode 2006, 1154).

Neuroscience confirmation of behavioral "anomalies"

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, 2002; Glimcher, Dorris and Bayer, 2005). Schultz, Dayan and Montague (1997) measured the activity of these neurons while thirsty monkeys sat quietly and listen for a tone which 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 per second 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.

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 references 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 amygdale 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. 2006, 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. 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 .

The Relative Income Effect – Brosnan and de Waal (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 within 60 seconds. When one monkey saw another receiving a more desirable reward (a grape) the monkey would not only refuse to participate in further exchanges, they would 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. (Brosnon and de Waal, 2003, 299)

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, Dorris and Bayer (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).

Rational Choice and Actual Human Behavior

The view is widespread that animal behavior justifies the economic rational actor model. Gintis (2006b, 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, Loewenstein and Prelec (2005, 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.

For from describing higher-order, complex 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.

III. Is a unified theory of human behavior possible?

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 2006a). 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 (2006a, 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 [Gintis 2006a] paper. The analytical tools deployed in this task incorporate core principles from several behavioral disciplines.

Making the economic model of behavior compatible with known facts from other behavioral sciences will not be an easy task. As Pesendorfer (2006, 712) points out, behavioral economics is largely organized around the failures of standard economics rather than being a stand-alone alternative. On the other hand, results from behavioral economics, game theory, and neuroscience show clearly that simply modifying the basic *Homo economicus* assumptions will not yield a satisfactory model of human behavior. If the self-regarding agent assumption is dropped, the Walrasian system collapses. Arguments about what is "rational", "irrational" or "anomalies" have led nowhere. 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 (Reiskamp, Busemeyer, and Mellers 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 allows us to avoid 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 2006b, Hodgson 2004, Richerson and Boyd 2005). In Hodgson's (2004, 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.

Generalized Darwinism relates to the role of incentives in "selecting" kinds of human behavior. The behavioral literature calls into question an 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, Norton 2004, O'Neill and Spash 2000, Sagoff 1988). As discussed above, using monetary incentives to promote the social good can have a perverse effect. The 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.

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 should begin by identifying the incentives for selfish behavior in the "atmospheric commons" and then finding ways to minimize incentives for this behavior and maximize those for cooperative solutions.

Another distinguishing characteristic of human thought is that humans can perceive the future (Searle 2001). Apes can figure out how to rationally manipulate tools to get food immediately but have only a rudimentary ability to plan to get food in a week or a month. Our ability to assess the future consequences of present actions, and behave accordingly, may be the main hope for preventing catastrophic climate change.

IV. 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 existence 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. Until the 20th century CO2 levels were under 300 ppm for the past 650,000 million years, at least. The pre-fossil fuel era level was about 280 ppm. In 2006 it was 384ppm and with business-as-usual it is projected to increase to 600ppm by 2050. CO2 levels could reach 2000ppm 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 1200ppm sometime in the next century.

As shown in Table 1 about 4000 gigatons (10^{9} tons) of carbon are stored in the atmosphere, forests, soils, and the upper ocean. There is much more in the deep ocean but this carbon does not interact with the rest on a timescale relevant to this discussion (Kasting 1998).

Table 1. Carbon in the Environment and Carbon Stored as Fossil Fuel

Reservoir	**Size in gigatons**	
Atmosphere	**750**	
Forests	**610**	
Soils	**1580**	
Surface Ocean	**1020**	
Deep Ocean	**38,100**	
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. these numbers are from 1994, need to be updated but the basic picture today is the same]

Remarkably, twenty-five percent more carbon than this is stored in fossil fuels (5000 gigatons). About one-half the carbon released by fossil fuel burning ends up in the atmosphere. Deforestation also releases carbon and this activity contributes about one third of the human-caused additions to atmospheric CO2.

As a result of fossil fuel burning and deforestation, the global average surface temperature rose by about 0.6C in the twentieth century and the rate of increase appears to be accelerating. Global average temperatures are projected to increase by between 1.4 and 5.8C by 2100 and to continue to rise long after that (Dow and Downing 2006, 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, agricultural disruption, the spread of infectious diseases, and biodiversity loss.

There is about seven times the amount of currently accessible carbon stored in fossil fuels as is now in the atmosphere. The burning of petroleum and natural gas is a major problem—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% 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 a significant fraction of these reserves are burned the results will likely be catastrophic. The amount of carbon stored in coal is so vast that if coal continues to be burned, feasible mitigation options will have a negligible effect on stabilizing atmospheric CO2 (Caldeira and Kasting 1993). To stay near the bottom of the projected range of global temperature increase, global CO2 emissions will have to be quickly reduced to 10-20% of current emissions (Shepherd 2006). [Most of the above is this from John Shepherd, Tyndall Centre for Climate Change Research, University of Southampton.]

Most coal is burned to generate electricity. What are the options for replacing this vast and cheap source of energy? Re-forestation can only have a negligible effect (Shepherd). 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. If we are to stabilize the global climate at levels at 2-3C above current temperatures, we need to phase out the use of fossil fuels, especially coal. According Socolow et al. (2004), to keep atmospheric CO2 at double its pre-industrial level, we need to keep emissions under the current level of 7 gigatons until 2054, then a rapid decline after that. If this is not done the results will certainly be a very different planet. If climate stability is the goal, we need to begin phasing out fossil fuel use .[8]

Most economists dealing with climate change focus on the rational allocation problem, that is, 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 fuels.[9] The overwhelming problem is how to sharply reduce, then eliminate, CO_2 emissions, not how to theoretically allocate some given amount of carbon (Rosen 2006, Socolow 2005).

V. 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, Loewenstein, and Prelec, 2005; Reiskamp, Busemeyer and Mellers, 2006). The next step is to replace the rational actor model of public policy with one that incorporates the regularities of human behavior uncovered by behavioral science.[10] How can global warming policies be designed based on behavioral science?

Beyond rational choice and optimization – 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, 2004b). 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 distribution (through lump sum transfers) so as to create the conditions for the nirvana of 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 terms of responsibility to future generations, the only policy "choice" is choosing the social rate of discount (see for example Dasgupta's (2006) criticism of the Stern report). Given the simplistic assumptions of the model, everything else takes care of itself.

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 (see section VI), but economists should have more to say about public policy than assigning property rights and adjusting relative prices.[11] 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 culturally conditioned, and that a broadly defined incentive structure should be part of pubic policy.

Beyond monetary incentives – Another major problem with the get-the-prices-right approach is the body of evidence discussed earlier indicating that financial incentives can actually crowd out feelings of civic responsibility (Frey 1997). Monetary incentives may actually discourage the kinds of behaviors needed to solve collective social problems like global climate change. 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 like global warming can actually have perverse effects. As many environmental philosophers have argued (Norton 2005; O'Neal 1993) giving people a shared responsibility and appealing directly to a sense of the common good is a much more effective way of gaining acceptance for environmental policies.

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. This behavior is no more "natural" than any other of the thousands of behavioral patterns exhibited in human cultures throughout our history. 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, 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. Although changing this model may seem hopeless, it is important to remember the malleability of human behavior. 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.

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 "voting" 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 challenges we face since it involves changing the organizing principle of the industrial economy—abundant and cheap energy. Is there a threshold, or tipping point, that would trigger the consensus and political will to seriously attack the causes of climate change? Will there be a tipping point in climate change that will lead to collective action mitigating the danger of catastrophic change?

VI. Addressing climate change: A policy sketch

The behavioral model of rational economic man has dominated economic theory and policy for one hundred 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.

Policy Clue Number 1: Increasing consumption does not translate into increasing social 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". This applies not only to the developed world (Frey and Stutzer, 2002; Kahneman and Sugden, 2005; Layard, 2005) but also to the developing world.

Policy Sub-Clue Number 1a: Absolute income may not be 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 the 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 to minimize the 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 should be incorporated into climate change policy.

Policy Sub-Clue Number 1b: Development need not focus exclusively on increasing per capita consumption

"Development" in the third world need not follow the path of the industrialized nation 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 even further in calling for "distributive justice" 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 in the third world, they would also help alleviate the pressure on the atmosphere 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.

Policy Clue Number 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, 2003; Vogel, 2004; Sober and Wilson, 1998). For most of our existence as a species we live in small groups in hostile environments where cooperation was essential for survival. Groups of people that 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. Formulating policies that tap into our social and genetic heritage of cooperation offers the best hope for success.

Policy Sub-Clue Number 2a: Cooperation depends on the ability to punish free-riders

Boyd and Richerson (1992) argue convincingly 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 studies, and (3) costly punishment was positively correlated with altruistic behavior. These and other game theoretic experiments are invaluable in informing climate change policy.

Stiglitz (2006) calls for using the international trade framework to impose penalties on countries (like 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 2006, 2-3).

Policy Sub-Clue Number 2b: The question of fairness

A major issue in global climate change policy is the fairness of the policy with respect to developing countries. The undeniable fact is that we have reached a tipping point in global climate change because the industrialized world has pushed CO2 levels from 280ppm to 380ppm 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. A more radical idea is to put the revenues 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 (1997) 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 developing world for driving up CO2 levels during the past 100 years.

Policy Sub-Clue Number 2c: Real world cooperation depends on the specific context

Humans may be unique among mammals in the extent to which they cooperate with others. But it is also true that humans are almost unique in the extent to which they 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. There is a growing interest in the nature of social cohesion and its implications for the rise and fall of whole societies (see for example, Turchin 2005). Much more research is needed in this area with an eye toward policy implications.

VII. 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, altruism). This is critically important at this stage in the development of economic thought. The mechanistic worldview has collapsed, 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-material social values, and a shared sense of urgency. Given the overwhelming dominance of the consumption-as-happiness ethic in our culture, the task of finding 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 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 every faced by our species (David Attenborough, E.O. Wilson etc.). Even stabilizing future warming of the earth at 2-3C above its present temperature will require monumental efforts (Socolow

2005). The marginal approach of traditional economic analysis, with its near exclusive emphasis on prices and property rights, is not up the task of sufficiently changing individual behavior and the structure of economic production. 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.

End Notes

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, rational choice theory, the canonical model (Henrich et al. 2001), or the axioms of consumer choice, among others. Gintis (xx) also uses the term rational actor but in a way so as to include a much wider array of human behaviors than the once standard economic model. The term "Walrasian" will be used to describe the general equilibrium system of traditional economics with its key assumptions of rational actors and competitive equilibrium.

2. Referring to the idea of economists that "irrational" behavior is the product of ancient emotional systems within the brain, Glimcher, Dorris, and Bayer (2005, 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 rational."

3. Some reviewers 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, etc. should not be flatly contradictory as they are now. This does not contradict, for example, Norgaard's (1989, 2006) notion of "methodological pluralism." But it does mean weeding out, using the scientific method where possible, those theories 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. *Homo economicus* should accept any positive offer. Results from the game show, however, that the majority of proposers in Western countries offer between 40 and 50% of the total and that offers under 30% of the total are usually rejected because they are not "fair" (Nowak, Page and Sigmund, 2000). These results have held up even when played with substantial amounts of real money (Gowdy, Iorgulescu, and Onyeiwu, 2003).

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.

6. Garrett Hardin's classic 1968 paper 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 over use. Concessions to the

common good are part of our evolutionary heritage and if enforced by effective punishment can mitigate the free riding problem.

7. During the Late Pleistocene Thermal Maximum the earth's average temperature rose by about 7C. This sudden temperature rise lasted for about 150,000 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, Carbon emissions are rising faster than ever. Annual carbon emission grew by about 0.8% from 1990 to 1999. From 2000 to 2005 they grew by 3.2% 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).

9. For critiques of economic models of climate change see Gowdy (2004b), Laitner, Decanio and Peters (2001), and Spash (2002).

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 (Benartzi and Thaler (2004), encouraging fertilizer adoption in Kenya (Duffo, Kremer and Roberinson 2005), and improving the reliability of identifications in police lineups (Wells et al. 2000).

11. Rosen (2006) points out that the U.S. generates about 5.5 times the world's average amount of carbon per capita. To do our part in achieving a 50% reduction, and taking equity into account, the U.S. would have to cut carbon emissions by a factor of 11 (1/2 times 1/5.5). This would be a 91 percent reduction. A carbon tax high enough to achieve this cutback would amount to $100 or more per ton and would most likely be economically catastrophic. A smaller carbon tax would get us part of the way toward stabilizing CO2 levels but numerous other policies would be required.

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