Economics for a Warming World

Frank Ackerman* [Tufts University, USA]

It is the ultimate challenge for public policy: the fate of the earth quite literally depends upon how society, in this generation, responds to the threat of climate change. As temperatures and sea levels continue their inexorable rise, as increasingly violent extremes of weather besiege communities and ecosystems, as accelerating environmental degradation threatens future supplies of food, water, and other necessities of life, how should the appropriate policies be chosen and implemented? What theories and analytical frameworks offer effective guidance for these crucial decisions? Economics seeks to provide systematic approaches to developing public policies; climate change is the final exam, the test that counts for any theory of policy formation. So far, unfortunately, the discipline is not headed for a very impressive grade.

This paper argues that new assumptions and analyses are needed in economics in order to comprehend and respond to the problem of climate change. Part I briefly introduces the reasons why climate change requires new and different policy analyses. Part II examines the ways in which aspects of established economic theory impede rather than encourage solutions to climate change. Part III concludes with recommendations for a revised approach to public policy.

1. The Problem(s) of Climate Change

Current patterns of fossil fuel combustion, deforestation, and other causes of greenhouse gas emissions will, within 50 to 100 years (if not sooner), cause massive melting of glaciers and ice sheets, extinctions of many climate-sensitive species, widespread droughts in (at least) South Asia, Africa and western North America, declines in global food production (even as population grows well beyond today's levels), and more destructive extreme weather events along the lines of the Gulf Coast hurricanes of 2005 and the European heat wave of 2003. And the news will only continue to worsen as atmospheric carbon dioxide levels rise.[1]

Three fundamental features of the climate problem challenge traditional assumptions and require new approaches in economics. Each is involved, to some extent, in other contemporary policy problems, but each is central to an understanding of climate change.

A. The Status Quo Is Not an Option

The urgency of the climate problem, the ever-increasing scientific certainty that "business as usual" will lead to irreversible, unacceptable outcomes, undermines the deep-seated analytical presumption in favor of the status quo. What climate science tells us, above

* Global Development and Environment Institute (GDAE), Tufts University. E-mail Frank.Ackerman@tufts.edu . This paper is excerpted from Lisa Heinzerling and Frank Ackerman, "Law and Economics for a Warming World," forthcoming in *Harvard Law and Policy Review* (2007).

[1] Support for these assertions about the nature of the climate change threat can be found in *Intergovernmental Panel On Climate Change, Third Assessment Report* (2001), *and Intergovernmental*

all, is that the status quo is not going to remain one of the available options.

This is not an isolated externality in an otherwise perfect market system, nor a simple harm with a straightforward remedy. The traditional, often implicit assumption of a higher burden of proof for those who want change than for those who oppose it may be obsolete if the world is in fact headed rapidly for a cliff. *Something* new and different has to be done; the remaining points illustrate the difficulties in deciding exactly what to do.

B. Causal Links Between Actions and Impacts Extend Across Centuries

The science of climate change involves causation across extraordinary spans of time. Carbon dioxide, the most important greenhouse gas, has a half-life in the atmosphere of a little over a century. Other processes are even slower: when the temperature of the atmosphere changes, several centuries are required for the depths of the oceans to reach a new thermal equilibrium. For this reason, it has been estimated that even if greenhouse gas emissions dropped back to pre-industrial levels today, sea levels would continue to rise, primarily due to thermal expansion of ocean water, for another 300 years. As bad as some of the near-term changes in climate may be, the greatest damages, arising from today's carbon emissions, will occur more than one lifetime into the future.

C. The Consequences and Probability of Climate Change Are Incalculable in Detail

Looking farther into the future yields forecasts of climate change that become increasingly dire in general, but also increasingly uncertain in detail. To some extent this growing uncertainty is an inevitable feature of forecasting, as the cumulative effect of small errors and unexpected events makes any prediction become fuzzier as it looks farther ahead. But there are additional sources of uncertainty that are specific to climate change: even in the short run, climate models predict increasingly variable weather, with more frequent and intense storms, droughts, floods, and heat waves. Yet in the foreseeable future there will not be any possibility of predicting even next year's hurricanes, let alone the pattern of hurricanes over time, in any useful detail. Nevertheless, increasing climate variability will, in the near term, be a greater problem than the gradual, predictable increases in average temperatures and sea level.

Even more uncertain is the risk of an abrupt and effectively irreversible catastrophe. Possible climate catastrophes include the melting of major Greenland or Antarctic ice sheets, causing much greater sea level rise; the sudden release of large amounts of methane from tundras or other regions, leading to an acceleration of warming; and the disruption of thermohaline circulation, turning off the Gulf Stream and rapidly cooling the North Atlantic. Climate models now predict that these and other catastrophic events *could* be triggered by enough warming and associated physical changes. However, the exact causal mechanisms remain too uncertain to identify a specific threshold at which such events will occur. At present it is only possible to say that the probabilities of various catastrophes, while still relatively low, will increase rapidly with rising temperatures and carbon dioxide levels.

Both the prediction of increasingly variable weather and the uncertain but growing risk of catastrophe defy attribution of specific harms to specific causes. The frequency of extreme

---

Panel on Climate Change, Fourth Assessment Report (2007), both available at http://www.ipcc.ch .

weather events was not zero before climate change began. So even if heat waves and hurricanes are now occurring more often as a result of climate change, there is no way to determine whether any one particular event is due to climate change. Even harder to determine is the probability of a global climate catastrophe that has never yet occurred; one can be certain that the probability is increasing due to global warming, without knowing precisely what the probability is.

2. Implications for Economics

Standard economic theory is poorly positioned to deal with a problem like climate change. Conventionally, economics prefers nonintervention in markets; it trivializes the future; and it takes a narrow, reductionist approach to environmental impacts, or "externalities." The result, all too often, is an analysis that calls for doing almost nothing about climate change, because the costs of doing more would exceed the (discounted, monetized) benefits. The economic case for inaction appears less controversial, and thus more powerful, than the arguments of the climate skeptics; economists can recognize the seriousness of the latest scientific findings and still maintain that the optimal policy is to move very slowly and timidly. Yet the economic theories behind these analyses do not withstand scrutiny.

A. Inaction as Equilibrium

Neoclassical economic theory reflexively shuns intervention in private markets. The status quo is thought to represent a market equilibrium, a state of affairs that cannot be improved upon without hurting someone. Even though few economists would argue that the world currently reflects this utopian ideal, many do assume that we are close enough to it that only small intrusions in the market, in the nature of tidying-up rather than major renovations, are required. This theory does not come close to describing the world we live in, and it arises from highly contestable normative assumptions about the importance of free markets to human freedom.

The starting point for neoclassical economic theory, the basic model to which other situations and policy options are compared, is a system of perfectly competitive markets, populated exclusively by small producers and atomistic consumers, all possessed of very broad information and very narrow motives and desires. In such an economy, under long lists of unrealistic assumptions, the well-known "fundamental theorems of welfare economics" demonstrate that a market equilibrium always exists, and is Pareto-optimal -- that is, that any deviation from that state of affairs will make *someone* worse off. The same theorems also posit that any Pareto optimum is a market equilibrium, for some initial distribution of resources. Environmental problems appear only as an afterthought, in the form of externalities: unpriced damages imposed by one party on another. Externalities, it is assumed, can be given prices and internalized, whether through Pigouvian taxes, Coasian negotiations, or the invention of markets for pollution rights. With externalities correctly internalized, the optimal properties of market equilibrium are restored.

No one, presumably, views this as an accurate description of any large part of our twenty-first century world. For some economists, the Pareto optimality of general equilibrium is an ideal worth striving toward. More common is the claim that this apparatus is analytically useful: the implications of the perfect-market model can be worked out with mathematical precision, and then reality can be understood in terms of its (minor) deviations from the

model.

The centrality of equilibrium to economic theory is obvious from the following passage from a textbook on microeconomic theory (based on the course taught to Harvard graduate students):

> "A characteristic feature that distinguishes economics from other scientific fields is that, for us, the equations of equilibrium constitute the center of our discipline. Other sciences, such as physics or even ecology, put comparatively more emphasis on the determination of dynamic laws of change."[2]

Ironically, the "equations of equilibrium" in economics arise from models borrowed from the physical sciences of an earlier era. The general equilibrium of a system of perfect markets bears more than a passing resemblance to the thermal equilibrium of an ideal gas. This is no coincidence; the late nineteenth-century founders of neoclassical economic theory were impressed by, and explicitly relied on, the accomplishments of nineteenth-century physics, including equilibrium thermodynamics.[3] The analogy to equilibrium thermodynamics was proudly acknowledged in the mid-twentieth century work of Paul Samuelson, who did so much to formalize the mathematical treatment of economic theory.[4] Yet the analogy between physics and economics was flawed and incomplete. The same analytical framework that worked so well in physics was much less fruitful when applied to economics.[5]

Equilibrium in the natural sciences has become a complex notion with multiple shades of meaning, some of them inconsistent with standard economics usage.[6] Moreover, economics has barely been touched by the twentieth-century development of disequilibrium theories, in thermodynamics and elsewhere in science, and the rise of complexity theory, which provides at least a heuristic mathematical explanation of long-lasting patterns of disequilibrium.[7]

The commitment to equilibrium theories in economics may reflect the fact that equilibrium in social sciences has normative as well as analytical significance. Thermodynamic equilibrium and disequilibrium are states of nature, with, presumably, the same neutral meaning to physicists of left-wing and right-wing political views. In contrast, equilibrium in the economic model of perfect markets is Pareto-optimal; within that model, market equilibrium maximizes efficiency, a desirable social goal. It has thus become bound up

---

[2] Andreu Mas-Colell, Michael Whinston, & Jerry Green, *Microeconomic Theory* 620 (1995).

[3] Philip Mirowski, *More Heat than Light: Economics as Social Physics, Physics as Nature's Economics* 193-353(1989).

[4] Paul Samuelson's classic *Foundations of Economic Analysis* x, 21, and 70. (Atheneum Press 1965) (1947) has a title page epigram--"mathematics is a language"--quoted from nineteenth-century physicist Willard Gibbs, and mentions the parallel of Samuelson's economics to Gibbs' thermodynamics.

[5] Mirowski, at 354-401; *see also* Frank Ackerman, "Still Dead After All These Years: Interpreting the Failure of General Equilibrium Theory", 9 *J. Econ. Methodology* 119 (2002).

[6] *Equilibrium in Economics: Scope and Limits*, 1-73 (Valeria Mosini ed., 2006).

[7] On disequilibrium thermodynamics, *see, e.g.,* Ilya Prigogine, *From Being to Becoming: Time and Complexity in the Physical Sciences* (1980); on complexity theory, *see* Stuart Kauffman, *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity* (1995); M. Mitchell Waldrup,

with advocacy of laissez-faire policies, seen by some as the route to political as well as economic freedom. In the words of Milton Friedman, "[T]he central feature of the market organization of economic activity is that it prevents one person from interfering with another in respect of most of his activities. . . . Underlying most arguments against the free market is a lack of belief in freedom itself."[8]

There are at least two major problems with this perspective. One is that the world of perfect markets, with only small, competitive businesses in every industry, is clearly unattainable in reality. Friedman and other advocates of laissez-faire tend to take it for granted that incremental movement toward an unregulated competitive market is desirable, since it brings the real world closer to the ideal. However, the "theory of the second best," established long ago by Richard Lipsey and Kelvin Lancaster, proves that if one of the requirements for Pareto optimality cannot be achieved, the best attainable (or "second best") outcome may require deviating from all the other aspects of the unconstrained optimum.[9] This simple, powerful idea undermines the significance of the competitive market model as a normative goal; since the goal is not, in its entirety, attainable, there is no guarantee that getting a little closer to it is on balance a good thing.

Second, Friedman's vision is of a world without important externalities: the normal operation of the market "prevents one person from interfering with another" in most of life's activities. The climate crisis consists precisely of the problem that market activities, and the resulting greenhouse gas emissions, are going to interfere rather totally with other people's lives. This is not a single, easily internalized externality; rather, climate change is a pervasive consequence of modern market activity, which ultimately threatens to undermine the continuation of the market economy which created it.

There have been economic theories that assumed a world in disequilibrium--or at least, did not assume the competitive, Pareto-optimal equilibrium of conventional models. The macroeconomics of John Maynard Keynes analyzed the phenomenon of persistent, involuntary unemployment, as did early theories of the business cycle (now largely ignored).[10] Outcomes that are far from Pareto-optimal also result from contemporary theories of asymmetric and limited information, and from new behavioral models that deviate from the traditional, selfishly rational *homo economicus.*[11] These theories, however, do not imply any inherent dynamic instability. In contrast, the climate crisis leads to a sense that normal market activity will ultimately undermine its own continuation.

A deeper sense of internal contradiction and instability was present in two very different branches of nineteenth-century political economy, in the writings of Marx and of Malthus. Of the two, Malthus was one step closer to the broad outlines of the climate problem; he was describing a way in which market activity would inevitably lead to environmental

---

Complexity: *The Emerging Science at the Edge of Order and Chaos* (1992).

[8] Milton Friedman, *Capitalism and Freedom* 14-15 (1962).

[9] Richard G. Lipsey & Kelvin Lancaster, "The General Theory of Second Best", 24 *Rev. Econ. Stud*. 11 (1956). By way of informal analogy, imagine that the fastest way to drive across a city is blocked by construction. The second-fastest option may be to take an entirely different route, not to stay as close as possible to the unattainable, normally fastest route.

[10] For the history of economic thought on this and other questions, *see* Mark Blaug, *Economic Theory in Retrospect* 14-15 (1997).

[11] *See* Joel Sobel, "Interdependent Preferences and Reciprocity", 43 *J. Econ. Literature* 392 (2005); Samuel Bowles, "Endogenous Preferences: The Cultural Consequences of Markets and Other Institutions", 36 *J. Econ. Literature* 75 (1998).

degradation, and thus ultimately to loss of incomes. However, the particular mechanism of Malthusian crisis, prosperity leading to population growth and rising demand for food, which eventually overwhelms the naturally limited productivity of agriculture, does not correspond closely to the major causal mechanisms of climate crisis. Something akin to the Malthusian crisis may be one of the consequences of climate change, as global warming is expected to reduce agricultural productivity relatively soon in the tropics, and perhaps after a few decades in temperate zones--but this is only part of a broader problem.

Natural constraints on economic growth have been raised more recently in ecological economics. This school of thought, drawing on the work of Herman Daly and others, has emphasized that the economy is embedded in the earth's ecosystems, which impose fixed limits on the sustainable scale of production and emissions. While this represents a promising contribution, with obvious relevance to climate change, it has yet to develop a comprehensive new synthesis -- and it has not had any significant influence on economic theory in general.

The challenge of climate change makes the traditional vision of perfect markets even less appropriate and useful. A world in which business as usual threatens to cause disaster in a century or less -- i.e., the warming world which we do inhabit -- is not usefully modeled by theories in which stable, optimal equilibrium is the normal state of affairs. Yet the notion that the market economy is or could easily be at equilibrium permeates economic theory; market equilibrium is generally taken to be desirable, and implicitly assumed to be sustainable. Indeed, if conventional theories of optimal market outcomes encourage a public policy of inaction on climate change, these theories may ironically hasten the arrival of a decidedly suboptimal, disequilibrium state of affairs.

B. Dismissing the Future

As every economics student learns, the standard approach to future costs and benefits is to convert them to the equivalent present values. At a fixed annual interest rate of 5 percent, $100 placed in a savings account today will, after 10 years, be worth $162.89. On the other hand, if you have to wait ten years before receiving the $100, it is worth only $61.39 today; that is, $61.39 is the amount of money you would need to put in the bank today, at 5 percent interest, to end up with $100 ten years from now.

For purely financial decisions covering a few years or decades, the logic of discounting is unimpeachable (if interest rates remain fixed), and indeed essential for understanding loans and other contracts. But when stretched across generations or centuries, the same techniques of discounting lead to the paradoxical conclusion that the future doesn't much matter. The traditional calculation of present values now faces the climate challenge: how can the logic of discounting be squared with the importance of avoiding disasters far in the future? Losses of trillions of dollars due to climate change, in future centuries, have such a small present value (at conventional discount rates, such as 3 percent or higher) that it is scarcely "worth" spending anything today to prevent the most drastic far-future harms.

While fixed-rate discounting is ubiquitous in economics today, its origins are modest: a six-page paper published by Paul Samuelson in 1937.[12] Samuelson introduced fixed-rate discounting tentatively, as a mathematical simplification of a complex problem, expressing

[12] Paul Samuelson, "A Note on Measurement of Utility", 4 *Rev. Econ. Stud*. 155 (1937). On the history of discounting, *see* Shane Frederick, George Loewenstein, & Ted O'Donoghue, "Time Discounting and Time Preference: A Critical Review", 40 *J. Econ. Lit*. 351 (2002).

doubts about its universal validity. Among his assumptions, he included:

> *The individual discounts future utilities in some simple regular fashion which is known to us.* For simplicity, we assume in the first instance that the rate of discount of future utilities is a constant . . . . [This assumption] is in the nature of an hypothesis, subject to refutation by the observable facts . . . .[13]

After completing the mathematical analysis, he observed,

> Our task now is to indicate briefly the serious limitations of the previous kind of analysis, which almost certainly vitiate it even from a theoretical point of view. In the first place, it is completely arbitrary to assume that the individual behaves so as to maximize [the present value of lifetime utility]. . . . [14]

Samuelson's formula spread quickly through the economics profession, while his doubts and qualifications were largely ignored. Several attempts were made to provide axiomatic foundations for discounting, of which the best known was by Tjalling Koopmans in 1960.[15] Koopmans proved that, under five seemingly innocuous assumptions, people act as if they are discounting the future at a fixed, positive rate. Among these assumptions was the idea that preferences are stationary, in the sense that if *A* is preferred to *B* at any one point in time, then *A* is also preferred to *B* if both are moved an equal distance forward or backward in time.

Survey research, however, has repeatedly found that preferences are *not* stationary, in Koopmans' sense; on the contrary, people exhibit "preference reversal" or "hyperbolic discounting," with lower implicit discount rates for choices and events farther in the future.[16] The fixed-rate model is also incompatible with the empirical findings that losses are discounted more slowly than gains, and that large amounts are discounted less than small amounts; since climate change involves the threat of very large losses, it would tend to be discounted more slowly -- at a lower rate -- than many other phenomena.

Nonetheless, many economists have continued to use the classic, fixed-rate formulation, perhaps assuming that its computational convenience outweighs its empirical inaccuracy. Others have embraced a newer modification (described below) that allows varying, usually declining, discount rates.

One response -- which increases the present value, and hence importance, of far future outcomes -- is to argue for a very low discount rate. The Stern review of the economics of climate change, conducted by Nicholas Stern for the British government, used a discount rate that varies by scenario, averaging 1.4 percent;[17] analyses by William Cline have used a

---

[13] Samuelson, *4 Rev. Econ. Stud*. at 156 (emphasis in original).

[14] *Id.* at 159.

[15] Tjalling C. Koopmans, "Stationary Ordinal Utility and Impatience", 28 *Econometrica* 287 (1960). For a response adding an axiom about concern for the future, and deriving a form of hyperbolic discounting, *see* Graciela Chichilnisky, "An Axiomatic Approach to Sustainable Development", 13 *Soc. Choice & Welfare* 231 (1996); Geoffrey Heal, *Valuing the Future: Economic Theory and Sustainability*, 69-75 (1999).

[16] This and the following discussion of empirical evidence on discounting anomalies are based on Frederick et al., at 360-65.

[17] Nicholas Stern et al., *Stern Review: The Economics of Climate Change* (2006), *available at*

similar rate of 1.5 percent.[18] Cline's own sensitivity analyses show that his cost-benefit justification for active climate policy diminishes rapidly with higher discount rates, and essentially vanishes at a rate of 3.5 percent or more.[19] Another economist, Richard Howarth, argues that if discount rates should be based on market interest rates, the appropriate rate to use is the after-tax return on risk-free investments, which averages close to zero in real terms.[20]

A second alternative is to employ hyperbolic, or declining, discount rates. Under hyperbolic discounting, far-future events may be discounted rapidly in the first few years, when discount rates are high; but the process is bound to slow down, as the discount rate drops toward zero over time. In addition to the empirical evidence that preferences are not stationary across time, there are two distinct theoretical arguments for declining rates -- one based on each of the major approaches to the choice of a social discount rate.

The "descriptive" approach to discounting assumes that interest rates and capital markets reveal society's time preferences.[21] In an idealized market economy, the equilibrium between the supply of private savings and the demand for funds for investment, which determines the interest rate, would also reflect individuals' tradeoffs between present and future consumption. Despite Howarth's argument for a low discount rate, noted above, many economists have concluded that average interest rates are much higher, sometimes 5 percent or more.[22] This is easily high enough to rule out all but the most trivial climate initiatives.

However, a new wrinkle on the descriptive approach analyzes uncertainty about future interest rates, thereby demonstrating that the effective discount rate should decline over time. There are multiple possible scenarios for future interest rates, each implying different present values for future events; if probabilities are assigned to these scenarios, the average present value can be calculated. As time goes on, the average is increasingly influenced by the lowest interest rate scenarios; so the effective discount rate is steadily declining.[23]

The alternative, "prescriptive" approach seeks to deduce the appropriate discount rate from ethical and philosophical principles.[24] In a framework that dates back to early work

---

http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

[18] William R. Cline, *The Economics of Global Warming* (1992); William R. Cline, "Climate Change", in *Global Crises, Global Solutions* (Bjorn Lomborg ed., 2004).

[19] *Id.*

[20] Richard B. Howarth, "Discounting and Uncertainty in Climate Change Policy Analysis", 79 *Land Econ*. 369-38, (2003).

[21] The categories of "descriptive" and "prescriptive" approaches to discount rates were introduced in Kenneth J. Arrow et al., *Intergenerational Equity, Discounting, and Economic Efficiency*, in James P. Bruce, Hoesung Lee, and Erik F. Haites, eds., Climate Change 1995: Economic and Social Dimensions of Climate Change (IPCC Working Group III, 1995), 125.

[22] *Id.*

[23] Martin L. Weitzman, "*Why the Far-Distant Future Should be Discounted at Its Lowest Possible Rate",* 36 *J. Envtl. Econ. & Mgmt*. 201 (1998); Richard G. Newell & William A. Pizer, "Uncertain Discount Rates in Climate Policy Analysis*",* 32(4*) Energy Pol'y* 519 (2004).

by Frank Ramsey,[25] the social rate of discount for long-term decisions is assumed to be the sum of the rate of pure time preference, or impatience, which would prevail if all generations had equal per capita incomes, plus a component due to the expected growth of incomes.[26] The latter, which has been less controversial, rests on the common assumption that future generations will likely be richer than the present, reducing the urgency of investing today's scarce resources on their behalf.

Most of the debate has centered on the rate of pure time preference. It has often been argued on ethical grounds that this rate should be zero: with equal resources, present and future persons should be of equal worth.[27] On the other hand, many economists have argued that a zero rate of pure time preference implies an absurdly high rate of savings: if incomes were not growing -- so the social rate of discount was zero -- then any gain for future generations that will last indefinitely, no matter how small, would justify large additional sacrifices in the present.[28]

It is not clear how, if at all, the rate of pure time preference would be expected to change in the future. The income-related component of the social discount rate, though, could easily vary. The flip side of the usual optimistic story about richer future generations is that, if our actions or omissions (failing to restrain carbon emissions) make future generations poorer, the discount rate should drop to reflect the growing urgency of providing for our descendants. That is, environmental crisis could itself cause declining discount rates. In extreme cases it could even lead to negative discount rates, i.e. valuing future outcomes more heavily than the present because future generations will be poorer than the present.[29] As Partha Dasgupta has pointed out, economists' judgments about the severity of climate change can influence their choice of discount rates: those who anticipate more limited climate damages will project faster income growth, less impeded by environmental constraints--and hence higher discount rates, which tilt the analysis toward "proving" that not much needs to be done.[30]

In sum, discount rates could be declining because that's how people empirically think about the future, because uncertainty about future interest rates makes the lowest-rate scenarios most important as time goes on, and/or because climate change itself will reduce future incomes, making our descendants less able to provide for themselves. One might hope that any or all of these stories would eliminate the paradox of discounting and validate future-oriented policies.[31] Unfortunately, the paradox is more stubborn than that: if discount rates start high enough, their impact in the early years can shrink the present value of far-future

---

[24] Arrow et al.. note 21.

[25] Frank P. Ramsey, "A Mathematical Theory of Saving", 38 *Econ. J*. 543 (1928).

[26] *See* Frank Ackerman & Ian J. Finlayson, "The Economics of Inaction on Climate Change: A Sensitivity Analysis", 6(5) *Climate Policy* (2006).

[27] See Heal, at 12, and sources cited there.

[28] *See e.g.*, Kenneth J. Arrow, "Discounting, Morality, and Gaming", in *Discounting and Intergenerational Equity* 13 (John P. Weyant & Paul R. Portney eds., 1999).

[29] Partha Dasgupta, Karl-Goran Mäler & Scott Barrett, "Intergenerational Equity, Social Discount Rates, and Global Warming", in *Discounting and Intergenerational Equity*, at 51.

[30] Partha Dasgupta, *Human Well-Being and the Natural Environment* 183-86 (2001).

[31] This was the view of David Pearce and his coauthors, in David Pearce et al., "Valuing the Future:

outcomes to insignificance; declining discount rates thereafter have only negligible effect. As a result, the calculation of costs and benefits in the near term assumes disproportionate importance. While much of climate science addresses very long-term concerns, hypotheses about costs and benefits in the first few decades can be decisive for calculations based on present values.[32] Thus cost-benefit calculations, based on present values and heavily influenced by the very short run, are answering a different question from the one that most people are asking about the ominous long-range implications of climate change.

C. Beyond Externalities

Mainstream economic theory insists on looking for evidence of market failure before sanctioning government intervention in the market. One of the signs of market failure is the presence of externalities. While the field of environmental economics recognizes the importance of externalities and rejects simple laissez-faire policy prescriptions, the prevailing understanding of externalities is inadequate to handle the challenge of climate change –- or other serious environmental problems.

The framing of the concept of externalities can be faulted on three grounds: the assumptions of separability, predictability, and monetizability all fail to convey the extent and intractability of environmental crisis.

Externalities, as described on the blackboard and in textbooks, happen one at a time; each one has a distinct cause, and is eligible for its own policy response. This assumption of separability may be helpful for introductory exposition, but it does not correspond well to the bewildering complexity of multiple, dissimilar impacts that will result from climate change. Yet the entire theory of externalities treats them as separable. From Pigou's original formulation to contemporary versions of environmental economics, an externality is understood as a single effect of a single cause.

Closely related is the implicit assumption that externalities are not very numerous; clear up a few of them and the market will presumably be back to its optimal self. The development of policies for individual externalities, whether based on taxes, negotiations, cost-benefit analyses, or creation of new markets in emission allowances, is a relatively costly, time-consuming process. Months, if not years, of Congressional and regulatory attention, combined with lengthy, controversial cost-benefit analyses, have been required to address individual pollutants such as arsenic in drinking water. For that reason, the presumption that externality pricing is feasible, without discussion of the time and resources consumed in the pricing process, must imply that the process is also relatively rare. The efficiency of the private market rests on its ability to calculate and communicate commodity prices, with little or no information costs; in contrast, the construction of hand-crafted prices for individual externalities appears anything but efficient.

Realistic environmental economics, in a world of entangled, multiple impacts from common causes, requires the development of policies that address the common causes, such as climate change. To be feasible, this needs to be done without the long detour through separate calculation and valuation of each of the individual harms.

Externalities are also assumed to be predictable; a well-defined harm is assumed to

---

Recent Advances in Social Discounting", 4 *World Econ*. 121, (2003).

[32] For example, the weakly supported assumption of large near-term benefits of moderate warming in DICE, a well-known climate economics model, is analyzed in Ackerman & Finlayson.

be associated with a specific cause. Economists have extended this analysis, to allow for uncertainty based on known probability distributions; in such cases it is possible to calculate the expected value of the uncertain outcomes. However, climate change, as noted above, is not predictable in any detail. This is only partly because knowledge of climate change is incomplete; there has rarely, if ever, been a scientific problem that was so well researched. Rather, the unpredictability often results directly from what *is* already known about climate science.

In particular, the earth's climate is known to result from a complex, highly non-linear system of physical interactions, with numerous positive and negative feedback loops. Models of such systems involve the mathematics of chaos and complexity theory, which are inherently unpredictable in detail; in some cases, only the average behavior of the system, or the maximum and minimum possible results, may be known. Indeed, "sensitive dependence on initial conditions," [33] a hallmark of chaotic dynamics, first became well known through the work of Edward Lorenz with a simplified model of the atmosphere.[34]

In a world of chaotic dynamics and sensitive dependence on initial conditions, econometric forecasting is of limited value; identification of specific expected outcomes, or even known probability distributions for specific future harms, will typically fail. Thus, it becomes meaningful to say that extreme weather events, for example, are known to be getting worse as a result of climate change, but it is impossible to say exactly how much worse, and how fast. The devastating Gulf Coast hurricanes of 2005 were followed by a very mild hurricane season in 2006; there is no way at present to anticipate how bad a single year's hurricanes will be. In this realm, policy formation based on prediction and calculation of expected harm is no longer relevant; the only coherent response to a situation of chaotically worsening outcomes is a precautionary policy, seeking to protect against the credible worst case events that might occur.

Finally, externalities are assumed to be monetizable; internalization of externalities requires quantitative estimates of monetary value. Lisa Heinzerling and I have written at length on the logical flaws, paradoxes, and absurdities of this process; interested readers should examine our previous discussion of the monetary value of human life, health, and nature.[35] Many economists engaged in valuation of externalities share some of these concerns, and express thoughtful qualifications surrounding their quantitative estimates; the Stern Review is exemplary in this regard.[36] Even the most rigorously quantitative analysts might have occasional qualms about assigning dollar prices to human life: should the value of life be based on wage differentials for risky jobs, on survey research about simplified, hypothetical risks, or something else entirely?[37] Should it be the same in Bangladesh as in Switzerland?

---

[33] This is the phenomenon sometimes described as the "butterfly effect": small initial changes can lead to much larger changes over time, so in theory a single butterfly flapping its wings could have visible effects on the weather on the other side of the world.

[34] See the Wikipedia entry on chaos theory, http://en.wikipedia.org/wiki/Chaos_theory

[35] Frank Ackerman & Lisa Heinzerling, *Priceless: On Knowing the Price of Everything and the Value of Nothing* (2004).

[36] This question is discussed repeatedly throughout Chapter 6 of the *Stern Review*, which summarizes the analysis of the costs of climate change. *Stern Review*, 143-167.

[37] As explained in *Priceless*, both wage differentials for risky jobs and survey responses about hypothetical risks have been used to value life, by EPA analysts under the Clinton and Bush

Yet these questions and qualifications, like Samuelson's doubts about the simple discounting formula that he unleashed on the world, are soon forgotten, as readers and policy makers rush to the "bottom line." Conventional economics offers results that are comfortingly definite: market outcomes are optimal and stable; discounted present values are the appropriate measure of future costs and benefits; externalities are easily evaluated and internalized. Seen through the lens of the climate crisis, these definite answers are definitely wrong.

3. Steps Toward Solutions

Embracing the status quo, dismissing the future, and ignoring consequences that cannot be described with absolute precision do not make for a good response to the problem of climate change. This final section offers three ways in which underlying principles and attitudes in economics must change if we are to act responsibly in the face of this threat. First, the development of climate change solutions requires a more optimistic and expansive vision of the role of the public sector. Second, it requires a different attitude toward regulatory costs, one that recognizes their potential to serve important public goals rather than simply their potential to drain private pocketbooks. Finally, addressing this problem requires a more sensible approach to considering the benefits of government action. The problem is real and imminent; the solutions are, in many cases, straightforward. Despite occasional claims to the contrary, nothing in economics requires us to ignore common sense and fail to protect ourselves and our descendants.

A. Public Choice and Government Competence

As a really big problem, climate change requires really big solutions. New technologies for energy production and use will be needed, including changes in power plants, transportation systems, building design and construction, major appliances, and more. These will entail massive investments in research and development, and coordinated changes in infrastructure. There will be a need for sweeping changes in other sectors with significant impacts on greenhouse gas emissions, such as agriculture, forestry, and waste management. National and international coordination is essential, since climate change is a global problem, driven by the global total of greenhouse gas emissions.

The imperative of large-scale responses clashes with the current fashion of seeking to minimize the role of the public sector. Academic theory now almost dismisses the possibility that public policy and expenditures represent the public interest. A cynical and misnamed "public choice theory" suggests that narrow personal self-interest explains the behavior of government officials, elected decision-makers, and everyone else involved in the public policy process. Discussion of "rent-seeking" in the public sector, and the resulting problem of "government failure," parallel to market failure, creates the impression that private action and market competition are the only ways to organize society and allocate its resources. A new, conservative brand of "political economy" seeks to deduce public preferences and actions exclusively from private economic interests and the hypothesis of universally narrow, self-interested behavior.

Likewise, the current fascination with market-based policy instruments has led to widespread discussion of a "cap and trade" system of carbon emissions trading. A trading scheme could undoubtedly play a role in efficiently reducing emissions, but there is no reason

---

administrations, respectively.

to think that it is the only option, or is capable of solving the problem alone -- no reason, that is, unless the government is assumed a priori to be incompetent. Otherwise, one might easily stray into thinking about the potential contribution of fuel efficiency standards for motor vehicles, government promotion of renewable energy technologies, stricter appliance and lighting efficiency standards, support for mass transit, better low-income housing insulation, and countless other forms of "interference" with the market. None of these initiatives would be likely to succeed, of course, if, in the succinct words of former Republican Congressional leader Dick Armey, "The market is rational; the government's dumb."[38]

Economics will have to move well beyond that simplistically market-oriented level to help guide the development of effective climate policies -- beginning with a better understanding of choice and preferences. There is no formula for optimal public decision-making; instead, a deliberative process of discussion is required.[39] Public choices cannot be deduced from isolated, individual preferences; as Amartya Sen has observed, if your willingness to pay for a major environmental project is independent of everyone else's actions, you may not have understood the question (because a modest willingness to pay for a major project is potentially useful if everyone else is paying similar amounts, but guaranteed to be ineffective if no one else is contributing). Rent-seeking is far from universal in public service, and the haste to privatize public functions and deregulate markets has arguably allowed the colossal rent-seeking of the likes of Enron and Halliburton, beside which the greed of individual bureaucrats pales by comparison. Self-interest is not the only relevant motive, and is not a useful guide to public choice in matters affecting the entire globe over a multi-century time frame.

In short, an entirely different conversation about public goods and priorities is needed, one that respects the importance of the underlying values - and one that includes, but is not always dominated by, the best available information about costs. It is a conversation which, sadly enough, Americans have been able to have in recent years only about national security, protection against terrorism, and military spending. The empirical content of that conversation has remained controversial; recall the search for Iraq's alleged weapons of mass destruction. Unfortunately, while confidence in the public sector and its unquestioned responsibility for our collective welfare is alive and well in decisions about the military, it has wasted away in civilian life.

Climate change is a real threat to our national security; this time the weapons of mass destruction have been unequivocally found, not least in our own cars and power plants. If the public sector, despite rent-seeking and all the rest, can fight a ferocious, years-long war based on dubious intelligence, how much more should we able to do for the real thing?

B. Environmental Costs and Economic Development

The economic case for inaction on climate change rests on the belief that the costs of action outweigh the benefits. Much of the critique of this argument has turned on the treatment of benefits--i.e., the benefits of avoiding or limiting climate change. Those benefits turn out to be massive and growing, but, as we have seen, they are often located well into the future, incalculable in precise detail, and inherently priceless. The costs of climate policy, in

[38] Representative Dick Armey, Speech at the Pacific Research Institute (May 29, 1998) available at http://www.cbe.csueastbay.edu/~sbesc/trans.html.

[39] The impossibility of a formula for optimal decisions is established by Arrow's Impossibility Theorem. *See generally* Kenneth Arrow, *Social Choice and Individual Values* (1951).

contrast, will occur sooner than the benefits, and are more predictable market expenditures, with well-defined price tags. Despite this difference, the cost side of the ledger is often misunderstood: large expenditures on technologies and other means to address technology may turn out to be "benefits," not "costs."

The concern about the costs of climate policy, or of environmental protection in general, stems from the notion that the status quo is worth preserving, and possible to preserve. If current market outcomes were Pareto-optimal, every new regulation or program would make someone worse off, representing a loss of welfare; under this framework, the concern about regulatory costs, whatever its empirical merits,[40] would at least stand on firm theoretical ground. Yet as discussed in Part II, economic theory establishes the optimality of market outcomes only in an unrealistic model of impossibly perfect markets; since it is impossible to achieve "perfection" in this respect, the theory of the second-best shows that it may not be worthwhile trying to get a little closer. In a world that is inescapably second-best from a laissez-faire, perfectly competitive perspective, how should regulatory costs be interpreted?

The abstract theory of perfect markets threatens to distract attention from the central role which government policy has always played in economic growth and development--and will play again, as the world combats climate change. In the past, industrialization has relied on active government intervention, planning, and leadership, in virtually every one of today's high-income, developed countries.[41] Consider, for example, the (no longer fashionable) strategy of protecting infant industries from world trade until they have reached a scale that makes them internationally competitive. This was nearly universally applied in the past, including in England in the years just before the Industrial Revolution and in the U.S. throughout the nineteenth century.[42] If markets were perfectly competitive, protection of infant industries would simply result in welfare losses to consumers, outweighing the gains to producers. However, if markets are imperfect, with significant economies of scale, skillful assistance to infant industries can work well, nurturing them until they have reached adulthood and can take care of themselves. It is all the more essential if industrial development is path-dependent, creating a potentially permanent advantage for the first producer to achieve large scale and low costs.[43]

Government intervention continues to shape the U.S. economy; major industries do not always arise spontaneously through private innovation. Spin-offs from the massive military expenditures of the Cold War era include commercial aircraft, and hence the airline industry; personal computers, and consumer electronics in general (which became possible only after decades of military procurement of advanced and miniaturized electronics); the Internet (which began with a Defense Department research network); and, for better or worse, nuclear power. As the latter example suggests, not every spin-off is equally successful.

---

[40] For an argument that the costs of environmental protection are empirically quite small, *see* Frank Ackerman, "The Unbearable Lightness of Regulatory Costs", 33 Fordham Urb. L.J. 1071 (2006). This article does not address the costs of climate protection.

[41] *See generally* Alice H. Amsden, *The Rise of "The Rest": Challenges to the West from Late-Industrializing Economies* (2001), and Ha-Joon Chang, *Kicking Away the Ladder: Development Strategy in Historical Perspective* (2002).

[42] Frank Ackerman, "An Offer You Can't Refuse: Free Trade, Globalization, and the Search for Alternative", in *The Flawed Foundations of General Equilibrium: Critical Essays in Economic Theory*, 149 (Frank Ackerman & Alejandro Nadal eds., 2004).

Was the government expenditure that led to these new technologies a cost or a benefit to the economy? Millions of jobs and associated incomes were created, not only in the military and its direct suppliers, but also in the spin-off industries that were based on the new technologies. It is difficult to imagine that private markets on their own would have come up with better or cheaper alternatives if the world had been more peaceful and the U.S. government more firmly committed to laissez-faire throughout the second half of the twentieth century.

Just as the military, in contemporary political discourse, provides the remaining avatar of public competence and responsibility, so too in economics, it provides the best surviving American example of the positive, leading role of the public sector in industrial development. A twenty-first century war on climate change, if the nation and the world should choose to fight it, will create a new round of technologies and industries, initially dependent on government support, but ultimately achieving independent profitability. The U.S. started down this road once before, promoting conservation and renewable energy technologies in the response to the energy crises of the 1970s. In that era, initiatives by the federal government and by California launched the development of wind power. Although U.S. support waned in the 1980s, European governments provided additional assistance; today, wind power is a rapidly growing industry, which is competitive with other energy sources in appropriate locations, without preferential treatment or subsidies.[44]

The "costs" of combating climate change will have to include the development and commercialization of many more energy-saving and emission-reducing technologies. If they follow the path of wind power, or of civilian aircraft or computers, they may need decades of support and development before they take off on their own. Success is not guaranteed, as the travails of nuclear power demonstrate; it is of course necessary to spend public money wisely, to do everything possible to pick winners and avoid (or pull the plug on) losers. But the people employed in building and installing wind turbines, and the people thereby spared from inhaling power plant emissions, do not experience the 1970s subsidies to wind power as a cost. In a world of imperfect markets and path-dependent development, government initiatives may amount to choosing a path forward, not forcing a step backward.

C. The Mismeasure of Disaster

The relentless pressure for numerical measures of harm has led to studies seeking to monetize as much as possible of the damages expected from climate change. The Stern Review is one of the latest and greatest of these endeavors, estimating that business as usual will lead to annual climate-related global impacts of trillions of dollars of damages, or 5 percent of world GDP.[45] Much of the commentary on the Review, positive and negative, has seemed to assume that at last, there is a genuinely large number on the table.

On the one hand, it is significant that the "bottom line" damages estimate is several times larger than the cost of climate mitigation.[46] Assuming that the damages were all

---

[43] *See generally* Brian Arthur, *Increasing Returns and Path Dependence in the Economy* (1994).

[44] *See* Am. Wind Energy Ass'n, *Comparative Cost of Wind and Other Energy Sources* (2001), http://www.awea.org/pubs/factsheets/Cost2001.PDF. (Showing wind and fossil fuel electricity generation costs, without subsidies, to be roughly comparable based on 1990s California and federal studies; wind power costs have continued to drop since then.)

[45] Stern Review, 163.

[46] Most of the damages identified in the *Stern Review*, valued at 5 percent of world GDP (or more, in

meaningfully calculated (the more obviously speculative estimates in the Stern Review were reported separately, and led to even bigger numbers),[47] this would be sufficient--but, we believe, not necessary--to justify immediate, large-scale mitigation efforts.

On the other hand, that is the only significance of a huge monetary damage estimate. It is not a helpful estimate of what climate change as a whole will mean, and it should not be necessary to motivate active climate policy. It seems likely that many people do not know how big a trillion is (it has twelve zeros; it is a million million); a number of such unfamiliar and enormous magnitude loses its informational content not only for the general public, but for policymakers as well.

With numbers this large, it is almost impossible to grasp their meaning without a standard of comparison. Rather than focusing on trillions of dollars, it is easier to think about the Stern Review's projected five percent loss of GDP. This is certainly a large amount of money and resources, which is worth considerable effort to preserve. However, a five percent loss of GDP "now and forever" (the Stern Review's phrase)[48] is not a qualitative change of state. In a country growing at 2.5 percent per year, which is close to recent U.S. experience,[49] it is equivalent to stopping growth for two years, then resuming. In a country growing at well over five percent per year, as India and particularly China have been,[50] it is equivalent to stopping growth for less than twelve months, then resuming. Such a brief hiccup in economic growth is not at all comparable to the real losses anticipated from climate change.

By way of analogy, consider the damage to New Orleans and surrounding areas from Hurricane Katrina. Property losses amounted to $125 billion in some estimates,[51] many times the cost of building adequate levees that would have protected the city. It appears that Louisiana as a whole lost 15 percent of state income in the four months after the hurricane.[52] These facts, while significant, are not serious candidates for being the most memorable or

---

variants on the basic calculation; see note 93 below) can be abated at a cost of 1 percent of world GDP. *Stern Review*, 163, for damage costs; *Stern Review*, 232, for abatement costs.

[47] Other factors that raised the damage cost estimates were the assumption of higher climate sensitivity to CO2, an estimate for the value of non-market damages, and an estimate of the effect of equity weighting of outcomes. Combining all of these factors produces damage costs as high as 20 percent of global GDP. *Stern Review*, 163.

[48] The first of the *Stern Review*'s numerous uses of the phrase "now and forever" (describing annual, indefinitely recurring costs or benefits) occurs on 55.

[49] From 2001 to 2005, the U.S. had an average growth rate of real GDP of 2.4% per year. Bureau of Econ. Analysis, http://www.bea.gov/national/index.htm#gdp (last visited Mar. 4, 2007).

[50] From 1990 to 2004, GDP grew at an average annual rate of 10 percent in China and 6 percent in India. "World Bank, World Development Indicators 2006" at Table 4.1 (2006), http:/ /devdata.worldbank.org/wdi2006/contents/Section4.htm.

[51] Estimate by Swiss Re, a leading reinsurance company. See http://www.swissre.com.

[52] Louisiana was the only state in which gross state product (GSP) declined in 2005. Louisiana GSP dropped by $2 billion, whereas if it had grown at the same rate as the rest of the U.S. in 2005, it would have grown by $5 billion. Thus it apparently suffered a loss of $7 billion, or five percent of state income for the year. This loss presumably happened in the last third of the year, since Katrina struck on August 29. So the loss amounts to fifteen percent of state income for the post-hurricane months. Calculations based on Press Release, Bureau of Economic Analysis, Services and Goods Sectors Contribute to Strong Growth in Gross Domestic Product (GDP) by State in 2005 (Oct. 26, 2006) *available at* http://www.bea.gov/ bea/newsrel/GSPNewsRelease.htm. All incomes are measured at 2000 prices. Both the Texas and the Southeast region as a whole grew faster than the national average in 2005, as did Louisiana in 2004; thus it seems likely that Louisiana would have grown at least as fast as the

disturbing aspects of the tragedy of New Orleans. The video footage and newspaper photos of flood waters and devastation, the vivid descriptions of the loss of communities, the destruction of a way of life, and the needless loss of so many lives -- these are the impacts that everyone remembers. They are not well conveyed by the statistics on economic loss; at best, those statistics form small supporting details, helping to fill in the broad image of disaster.

Climate change will mean, among other things, more Katrina-like events. Alongside the staggering human and environmental losses, it will also have a large price tag, undoubtedly in the trillions. But the urgency of doing something about climate change does not stand or fall on a conjectural cost-benefit analysis, placing those trillions on one side of the scale. The impacts that matter most are the potential loss of communities, ecosystems, a way of life, and human life itself -- impacts that are priceless. The climate externalities that need to be internalized are deeper and more dangerous than prices can measure.

Despite their failings, studies like the Stern Review nonetheless serve a purpose in developing responses to climate change. There are people who pay attention only to numbers, and especially to numbers with dollar signs in front of them; massive cost estimates for climate damages speak to this population in a way that more qualitative descriptions of harm do not. Even for the rest of us, stories about the large costs of doing nothing about climate change can offset, to some degree, the unending stories about the large costs of doing something about it.

Economic analysis of the benefits of government action can thus play a catalytic role in addressing the problem of climate change. It cannot describe all of these benefits, nor even some of the most important ones. It cannot tell us what we should or should not do, nor can it overrule common sense and scientific urgency. It can start a conversation, but not end it.

In conclusion, how should we respond to emergencies, large and small? Our culture celebrates those who risk their own well-being to ensure the safety of others, without checking their watches or wallets; we applaud those who rush accident victims to the hospital, not those who check their health insurance status before admitting them. How differently should we react when all of us and our children are at risk, when the earth and its ecosystems are the potential victims of an accident waiting to happen? What is the purpose of our wealth and our institutions if not to protect our common future in the face of global threats? Theories that suggest otherwise, claiming that ancient academic precepts now counsel inaction, are theories in urgent need of replacement.

SUGGESTED CITATION:
Frank Ackerman, "Economics for a warming world", *post-autistic economics review*, issue no. 44, 9 December 2007, pp. 2-18, http://www.paecon.net/PAEReview/issue44/Ackerman44.pdf

national average in 2005, in the absence of hurricane damages.