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Applying the Precautionary Principle to Global Warming

by Indur M. Goklany

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Summary

The precautionary principle has been invoked to justify a policy of aggressive greenhouse gas (GHG) emission controls that would go beyond "no regrets" actions to reduce global warming. However, this justification is based upon selectively applying the principle to the potential public health and environmental consequences of global warming but not to the adverse consequences of such a policy.

This report attempts to rectify this one-sided application of the precautionary principle. It finds that such a policy, despite its claim to be precautionary, would, in fact, be incautious in many areas because it has a high likelihood of increasing overall risks to public health and the environment. Specifically, GHG emission reduction requirements that go beyond secular improvements in technology and elimination of unjustified energy subsidies could retard economic development, leading to greater hunger, poorer health, and higher mortality, especially in developing countries. Moreover, higher oil and gas prices would reduce food availability and would also retard switching from solid fuels to more environmentally benign fuels for heating and cooking in households of the developing world. Indoor air pollution resulting from current heating and cooking practices in these nations is a major source of premature deaths.

The precautionary principle, despite its claim to be precautionary, would, in fact, be incautious in many areas because it has a high likelihood of increasing overall risks to public health and the environment.

A truly precautionary principle argues, instead, for focusing on solving current problems that may be aggravated by climate change, and on increasing society's adaptability and decreasing its vulnerability to environmental problems in general and climate change in particular. These could be achieved by bolstering the mutually-reinforcing forces of technological change, economic growth, and trade. Moreover, enhancing adaptability and reducing vulnerability will raise the thresholds at which greenhouse gas concentrations could become "dangerous."

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Introduction

Article 3.3 of the 1992 U.N. Framework Convention on Climate Change states:

> The parties should take precautionary measures to anticipate, prevent or minimise the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost effective so as to ensure global benefits at the lowest possible cost.[1]

A plain reading of this section would require that the precautionary principle employ a cost-benefit framework.[2] However, more generic versions of the principle have sometimes been invoked as justification for going beyond "no regrets" actions[3] to address the potential threat of human-induced climate change[4] and to reduce greenhouse gas emissions beyond what might be achieved through secular (or normal) technological change or through reductions of economically inefficient subsidies.[5, 6]

A popular generic formulation of the precautionary principle is contained in the Wingspread Declaration: "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not established scientifically."[7] Under such a formulation, it has been argued that aggressive greenhouse gas control should be viewed as a precautionary measure, similar to an insurance policy, to forestall surprises or potentially disastrous consequences.[8]

Overlooked by this argument is the prospect that such an insurance policy itself might raise new—or aggravate existing—threats to human health or the environment.[9] The Wingspread Declaration's version of the precautionary principle offers no guidance in instances where a measure ostensibly designed to forestall uncertain public health and environmental problems might itself add to the world's health and environmental burden, thereby offsetting, if not negating, the presumed benefits of that measure.[10]

In a recent paper published by the Center for the Study of American Business, I presented a framework to resolve such dilemmas resulting from a narrow application of the precautionary principle and applied it to the specific issue of banning research, development, and commercialization of genetically modified crops.[11] Here I propose to employ the same framework to investigate whether it would be prudent to control GHGs beyond what would occur under "no regret" actions. In the parlance of the insurance business, I would, in effect, undertake a *qualitative* cost-benefit analysis of the insurance premium. This is, in essence, what nearly all individuals or families do before purchasing insurance, whether it is for life, health, or property. And, of course, the amount of insurance purchased (if any) is affected by alternative uses for these funds. Instead of using dollars and cents, however, I will use a more qualitative assessment of the effects on public health and the environment as the basis for the cost-benefit calculus. I will recapitulate my precautionary framework before applying it to control of greenhouse gases.

A Framework for Applying the Precautionary Principle under Competing Uncertainties

Few actions are either unmitigated disasters or generate unadulterated benefits, and certainty in science is the exception rather than the rule. How, then, do we formulate precautionary policies in situations in which an action could simultaneously lead to uncertain benefits and uncertain harms? A necessary first step is to formulate hierarchical criteria on how to rank various threats based upon their characteristics and the degree of certainty attached to them. Consequently, I offer six criteria to construct a precautionary "framework."

The first of these criteria is the *public health criterion*. Threats to human health should take precedence over threats to the environment. In particular, the threat of death to any human being outweighs similar threats to members of other species.

However, in instances where an action under consideration results in both potential benefits and potential harm to public health, additional criteria have to be brought into play. These additional criteria are also valid for cases where the action under consideration results in positive as well as negative environmental impacts unrelated to public health. I identify five such criteria as follows:

- *The immediacy criterion*. All else being equal, more-immediate threats should be given priority over threats that could occur later. Support for this criterion can be found in the fact that people tend to partially discount the value of human lives that might be lost in the more distant future.[12] While some may question whether such discounting may be ethical, it may be justified on the grounds that if death does not come immediately, with greater knowledge and technology, methods may be found in the future to deal with conditions that would otherwise be fatal which, in turn, may postpone death even longer. For instance, U.S. deaths due to AIDS / HIV dropped from a high of 43,115 in 1995 to 13,210 in 1998.[13] Thus if an HIV-positive person in the United States did not succumb to AIDS in 1995, because of the advances in medicine there was a greater likelihood in 1998 that he would live out his "normal" life span. Thus, it would be reasonable to give greater weight to premature deaths that occur sooner. This is related to, but distinct from, the *adaptation criterion* noted below.

- *The uncertainty criterion*. Threats of harm that are more certain (have higher probabilities of occurrence) should take precedence over those that are less certain if otherwise their consequences would be equivalent. (I will, in this study, be silent on how equivalency should be determined for different kinds of threats.)
- *The expectation value criterion*. For threats that are equally certain, precedence should be given to those that have a higher expectation value. An action resulting in fewer expected deaths is preferred over one that would result in a larger number of expected deaths (assuming that the "quality of lives saved" is equivalent). Similarly, if an action poses a greater risk to biodiversity than inaction, the latter ought to be favored.
- *The adaptation criterion*. If technologies are available to cope with, or adapt to, the adverse consequences of an impact, then that impact can be discounted to the extent that the threat can be nullified.
- *The irreversibility criterion*. Greater priority should be given to outcomes that are irreversible or likely to be more persistent.

In the following pages, I first will outline the potential benefits and costs to public health and the environment from aggressively forcing the pace of reductions in greenhouse gas emissions beyond what might occur because of secular improvements in technology (see endnote 6). I will then use the relevant criteria to determine the appropriate policy pursuant to a comprehensive application of the precautionary principle.

The Net Impacts of Global Warming

The net global and regional impacts of human-induced climate change (or global warming) are inherently uncertain. This is because projections of future impacts are based on a series of model calculations with each succeeding model using as its inputs increasingly uncertain outputs of the previous model.[14]

First, future emissions of greenhouse gases (GHGs) have to be estimated using uncertain projections of future population, economic conditions, energy usage, land use, and land cover. These emissions are themselves sensitive to climatic conditions and to atmospheric concentrations. Next, these emissions have to be converted into each GHG's atmospheric concentration. Third, these concentrations have to be used to determine future "radiation forcing" which is then used (ideally) by coupled atmospheric-ocean models to project climatic changes (such as changes in seasonal temperatures and precipitation, seasonal highs and lows, and changes in diurnal variability).

These climatic changes should be estimated at relatively fine geographical scales. This is because geography itself is an important determinant of the climate. Moreover, the distribution and abundance of natural resources, which are the basis of most climate-sensitive natural and human systems, are spatially heterogeneous. But regardless of how much confidence one may have in the ability of climate models to estimate globally-averaged climatic changes, the finer the geographic scale, the more uncertain the results.

Fifth, these uncertain location-specific climatic changes serve as inputs to simplified and often inadequate models that project location-specific biophysical changes (e.g., crop or timber yields). Then, depending on the human or natural system under consideration, the outputs of these biophysical models may have to be fed into additional models to calculate impacts on those systems. For example, estimates of crop yields in specific areas should serve as inputs for a model of the global agricultural system in order to estimate overall impact on food security.

Ideally there ought to be dynamic feedback loops between several of the models in the entire chain of models going from emissions to impact estimates. For instance, the climate affects photosynthesis and respiration on the earth's surface, which, in turn, will affect global CO_2 emissions. Therefore, there ought to be dynamic feedbacks from the impacts and climate models to the emissions models. But to ease calculations, these feedback loops are generally ignored or replaced by static inputs or "boundary" conditions.

Thus, estimates of the impacts of global warming in any specific location at any particular time are probably even more uncertain than estimates of the globally-averaged temperature and/or precipitation. Moreover, net global impacts—because they are an aggregation of the various location-specific impacts—are also uncertain, although there may be some cancellation of errors. Nonetheless, the uncertainties are large enough that one cannot be confident either of the magnitude or, in many cases, even the direction of impacts, i.e., whether the net impacts are positive or negative. This is true not only for any specific geographic location, but also globally.

Moreover, for climate-sensitive systems or indicators that are affected by human actions (e.g., agriculture, forests, land use, land cover, habitat loss, and biodiversity), impact models should include socioeconomic models, which ought to—but often do not—fully incorporate secular changes in technology and "automatic" adaptations, among other things. Failure to reasonably account for such technological change and human adaptability results in a substantial upward bias in the projected negative consequences of climatic change. Human ingenuity not only can mitigate adverse effects but also can harness positive consequences of climate change. The forecasting landscape is strewn with spectacular duds such as the Club of Rome's *Limits to Growth*, *Global 2000* or Paul Ehrlich's *The Population Explosion* because of failure to account for this factor.[15]

Regardless of the uncertainties surrounding the impacts, unless fossil fuel emissions from both developed and developing countries are curtailed drastically, a number of developments are likely. These developments include:

- Atmospheric carbon dioxide concentrations will most likely continue to rise. All else being equal, higher carbon dioxide concentrations mean greater productivity for agriculture, if not vegetation in general.[16] And greater agricultural productivity means more food, which leads to better nutrition, which, in turn, ought to result in better health, less disease, and lower mortality.[17] The remarkable increases in global agricultural productivity and global food supplies per capita since the end of World War II—despite a much larger population—have been accompanied by substantial worldwide improvements in health, reductions in mortality rates, and increases in life expectancies.[18] Most of the credit for these achievements is generally assigned to agricultural, medical, and public health technologies and practices, economic development (which makes more productive and improved technologies more affordable), and trade (which moves food surpluses to food deficit areas and generally stimulates both economic growth and diffusion of technology).[19] Nevertheless, some credit is due to the past increase in CO_2 concentrations and, perhaps, to any associated global warming.[20]

- Globally averaged temperatures will be higher, but the degree of warming and its geographic distribution is uncertain. There ought to be greater warming in the higher latitudes, at night, and during the winter. In general this means, among other things, greater agricultural and forest productivity in the higher latitudes because of longer growing seasons, but it could increase heat stress and reduce productivity in the tropics.[21] Although the contribution of warming *per se* to the historical increases in global agricultural productivity is not yet known, growing seasons and forest productivity have been increasing in the northern latitudes due, perhaps, to a combination of higher nighttime temperatures during the winter and higher CO_2 concentrations.[22] Similarly, Magnuson et al. find that freeze dates for river and lake ice seem to be occurring an average of 5.8 days later compared to 150 years ago, while thawing dates are occurring an average of 6.5 days earlier compared to 100 years ago.[23]

- Globally averaged precipitation may increase, although precipitation may decline in some areas. Also, the timing of rainfall may be altered. Increased precipitation does not necessarily translate into greater availability of moisture for growing crops and vegetation. In some areas, increased evaporation due to higher temperatures may, all else being equal, more than offset increased precipitation. On the other hand, the water use efficiency of vegetation goes up with increasing carbon dioxide concentrations. Thus, it is very difficult to predict the amount of water needed to grow specific crops and other vegetation at any given location.[24]

- Although there has been no discernible increase in the rate of sea level rise over the past century due to global warming, it could conceivably accelerate in the future.[25]

- Altered patterns of temperature and precipitation combined with increasing CO_2 concentrations will cause some

> animal and vegetation species to migrate. The ensemble of species, or "ecosystem," at any specific location today will thus be altered, as will the abundance of individual species at that location.[26] But whether these changes constitute a net benefit or loss is unclear. Not only is the "final" distribution of species uncertain, but there are also no criteria for establishing whether the change has resulted in a net loss or benefit to either humanity or the rest of nature. Proponents of GHG controls implicitly assume that any change is inherently detrimental, more as an article of faith rather than as the product of a rational inquiry into aspects such as changes in net or gross productivity, or the mix and abundance of species.

In addition, the potential spread of vector-borne diseases in a warmer world has been raised as one of the major concerns regarding anthropogenic climate change. Some fear that vectors such as the anopheles mosquito—the carrier of malaria—could become more widespread with warming because a change in climate could alter the range and abundance of species.[27] Malaria was estimated to have killed 1.1 million people in 1999.[28] However, historical data indicate that the prevalence of these diseases depends less on their potential ranges than on an understanding of their causes and the public health measures taken to deal with the vectors and the diseases they spread.

Malaria, cholera, and other diarrheal and parasitic diseases that were prevalent around the world, including in the United States and Western Europe, during the last century are today problems only where the necessary public health measures are unaffordable or have been compromised.[29] Thus, despite any warming that may have occurred, advances and investments in—and greater availability of—food, nutrition, medicine, and public health technology helped reduce infectious and parasitic diseases worldwide—particularly among the young in developing countries. As a result, crude global death rates dropped and global life expectancy at birth increased from 46.4 in 1950-55 to 64.3 years in 1990-95.[30]

It has been suggested that climate change may be a factor in the recent resurgences in vector-borne diseases in some parts of the globe.[31] Resurgences include malaria in Henan Province (China); malaria and dengue fever in the Americas; and cholera in Peru and Rwanda. However, increases in drug resistance; increased urbanization that can lead to unsanitary conditions that facilitate the spread of infectious diseases; premature discontinuation of control measures such as indoor spraying and use of impregnated mosquito nets; and faltering mosquito control and public health measures (e.g., reduction in DDT usage and chlorination) aggravated by poor nutrition seem to be more likely causes.[32] In many developing countries, malaria has retreated, advanced and, in some places, retreated once again as levels of in-home malaria spraying have increased, decreased, and, occasionally, increased again.[33]

Despite any warming that may have occurred, advances and investments in—and greater availability of —food, nutrition, medicine, and public health technology helped reduce infectious and parasitic diseases worldwide.

Although extreme temperatures pose lesser public health problems than infectious and parasitic diseases, they too are a source of concern for public health since extreme heat (as well as extreme cold) can lead to death and sickness.[34] Gaffen and Ross (1998) reported that between 1949 and 1995 the frequency of "extreme heat stress events" increased for the United States.[35] They suggested that continuation of this trend could pose public health problems in the future. However, analysis by Goklany and Straja of death certificate data from the Centers for Disease Control and Prevention,[36] shows no upward trends in U.S. crude death rates either due to excessive heat or excessive cold between 1979 and 1997, despite the aging of the population.[37] One explanation for this lack of a trend is that technological changes might have overwhelmed any increased risks due to meteorological changes.

Despite the uncertainties associated with the impacts of climate change and the previously-noted tendency to systematically overestimate impacts, I will in the following assume that, by and large, the IPCC's 1995 assessment of the future impacts of global warming are relatively sound. The IPCC's estimates suggest that in the absence of further GHG controls, over the next several decades the net impacts of global warming will be relatively small compared to other environmental and natural resource problems facing the globe (see Table 1).[38] Specifically, Table 1 shows that:

- In the absence of warming, global agricultural production would have to increase 83 percent from 1990 to 2060 to meet additional food demand from a larger and richer global population, according to one study relied upon by the IPCC's 1995 assessment.[39] Global warming may decrease production in developing countries but increase

Table 1

Projected Climate Change Impacts Compared to Other Environmental Problems

Climate-Sensitive Sector/ Indicator	Year	Impact/Effect	
		Baseline, includes impacts of environmental problems other than climate change	*Impacts of climate change, on top of baseline*
Agricultural Production	2060 for baseline >2100 for climate change	must increase 83 percent, relative to 1990	net global production would change -2.4 to +1.1 percent; but could substantially redistribute production from developing to developed countries
Global Forest Area	2050	decrease 25-30 percent, relative to 1990	*reduced loss* of global forest area
Malaria Incidence	2060	500 million	25 to 40 million additional cases
	2100	500 million	50 to 80 million additional cases
Sea Level Rise	2060	varies	less than 25 cm (or 10 inches)
	2100	varies	less than 50 cm (or 20 inches)
Extreme Weather Events	2060 or 2100	NA	unknown whether magnitudes or frequencies of occurrence will increase or decrease

Sources: Intergovernmental Panel on Climate Change, Robert T. Watson et al., eds., *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change* (Cambridge, England: Cambridge University Press, 1996); IPCC, John Theodore Houghton et al., eds., *Climate Change 1995: The Science of Climate Change* (Cambridge, England: Cambridge University Press, 1996); Indur M. Goklany, "The Importance of Climate Change Compared to Other Global Changes," in *Proceedings of the Second International Specialty Conference: Global Climate change, Crystal City, Virginia, October 13-16, 1998* (Sewickley, Pennsylvania: Air and Waste Management Association, 1998); Goklany, "Potential Consequences of Increasing Atmospheric CO_2 Concentrations Compared to Other Environmental Problems," *Technology* 7S (2000): 189-213.

it in developed nations, resulting in a net change in global production of +1 or –2 percent in 2060. Notably, that study, by Rosenzweig and Parry, used a globally-averaged temperature change for 2060 that was higher than the IPCC's "best estimate" for 2100.[40] Also, it considered only a few of the potential adaptations that could be available in 2060 (or, for that matter, 2100). For instance, it did not consider the potential for productivity-enhancing techniques such as development of cultivars that can better tolerate drought, salt, and acidic conditions, and that can better take advantage of higher atmospheric CO_2 concentrations. These technologies are merely gleams in our eyes today, but could be realities six decades from now, perhaps as a result of bioengineering.[41] On the other hand, the analysis did not consider any change in the proportion of crops lost to insects and other pests. Of course, crop protection is an ongoing challenge for farmers everywhere with or without climate change.[42]

- Regarding forest and habitat, greater agricultural and other human demands may reduce forest cover by 25 percent or more by 2050 in the absence of any global warming, putting enormous pressure on the world's biodiversity.[43] However, global warming alone—ignoring the beneficial effects of CO_2 on photosynthesis and water-use efficiency—may actually *increase* forest cover by 1 to 9 percent.[44] The existing boundaries of current forest types would, almost certainly, shift poleward. *A priori*, there is no reason to believe this would lead to a diminution of global biological diversity in terms of the number of species or their abundance. It is worth noting that, often, wetter and warmer climatic conditions seem to harbor greater biodiversity, so long as sufficient water is available.[45]

- By 2060, incidences of malaria (which may be thought of as a metaphor for climate-sensitive infectious and parasitic diseases) may increase by about 5 to 8 percent of the base rate in the absence of warming.[46] The increase may be double that by 2100. These increases, although small compared to the baseline rate, are nevertheless likely to be overestimates because the analysis is based on the notion that warming will expand the geographical ranges of the responsible vectors. This notion has been disputed by some authorities on tropical diseases.[47] Perhaps more importantly, the current ranges of these diseases seem to be dictated less by climate than by human adaptability.[48]

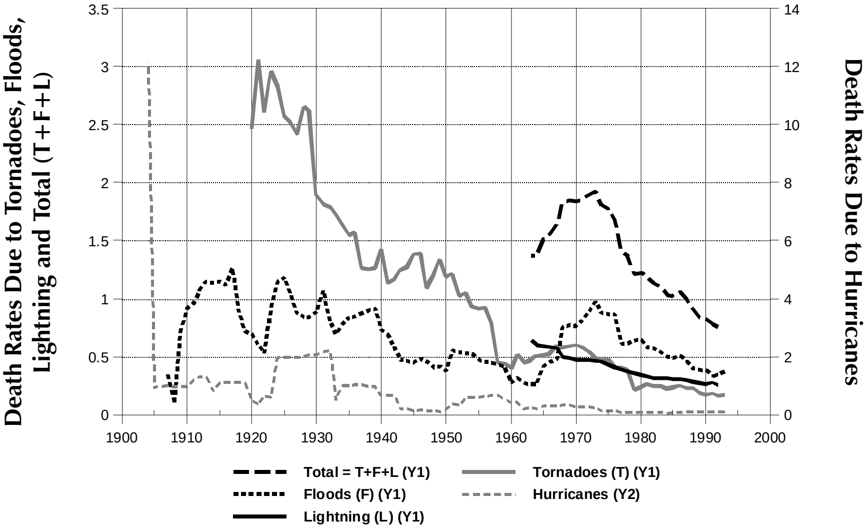
Many infectious and parasitic diseases (e.g., malaria, yellow fever, and cholera) have been virtually eradicated in richer countries although they were once prevalent there (e.g., the United States and Italy). This is because, in general, a wealthier society has better nutrition, better general health, and greater access to public health measures and technologies targeted at controlling these diseases. Given secular improvements in public health measures and technologies that ought to occur in the next several decades due to rapid expansion in our knowledge of diseases and development of institutions devoted to health and medical research, the importance of climate in determining the ranges of these diseases is likely to further diminish. Despite all these considerations, I will assume that the estimates of 5 to 8 percent by 2050 or 10 to 16 percent by 2100 are reasonable.

- Sea level could rise about 10 inches by 2060 and 20 inches by 2100 due to global warming. The cost of protecting structures and populations against a 20-inch rise in sea level by 2100 has been estimated at about $1 billion per year until 2100 or less than 0.005 percent of global economic product.[49]
- Proponents of establishing GHG emission limits have also speculated that the frequency and intensity of extreme weather events may be increased by global warming, as would deaths and damage due to such events. But so far there seems to be little evidence of that. In fact, despite any increased global warming during the past century, U.S. data show that in the past decades, death rates due to tornadoes, floods, lightning, and hurricanes have declined 60 to 99 percent since their peaks (based on nine-year moving averages (MA); see Figure 1).[50] In addition, although property losses due to floods and hurricanes have increased somewhat in terms of "real" dollars because a larger and richer population has more property at risk, losses have not increased in terms of percent of wealth (Figures 2 and 3).[51] Finally, there seems to be little scientific basis for concluding that in the future, extreme events will be more frequent or more intense due to global warming.[52]

Figure 1

Death Rates Due to Tornadoes, Floods, Lightning, and Hurricanes

(Deaths Per Million Population, Nine-Year Moving Averages, 1900-1997)



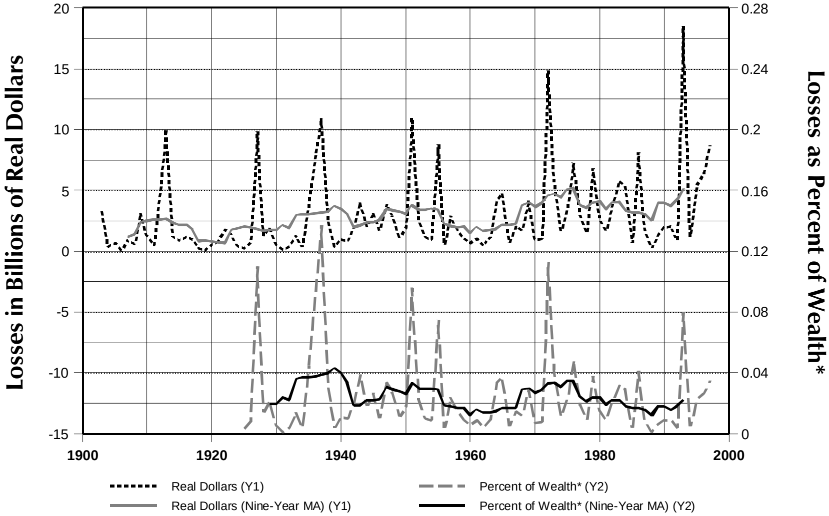
Sources: Indur M. Goklany, "The Importance of Climate Change Compared to Other Global Changes," in *Proceedings of the Second International Specialty Conference: Global Climate change, Crystal City, Virginia, October 13-16, 1998* (Sewickley, Pennsylvania: Air and Waste Management Association, 1998); Goklany, "Potential Consequences of Increasing Atmospheric CO_2 Concentrations Compared to Other Environmental Problems," *Technology* 7S (2000): 189-213.

Hence, stabilizing greenhouse gas concentrations immediately, even if feasible, would do little or nothing over the next several decades to solve those problems that are the major reasons for concern about warming, except, possibly, sea level rise (see Table 1). Specifically:

- Land and water conversion will continue virtually unabated, with little or no reduction in the threats to forests, biodiversity, and carbon stores and sinks.
- The feeding, clothing, and sheltering of a larger world population will not have been substantially advanced, if at all.
- Incidence rates of infectious and parasitic diseases will be virtually unchanged.
- Poorer nations, which by virtue of their poverty are deemed to be most vulnerable to the adverse impacts of climate change, will continue to be vulnerable to all kinds of adversity, natural or man-made.

Figure 2

Property Losses Due to Floods, 1903-1997



* Wealth measured as fixed reproducible tangible assets.

Sources: Indur M. Goklany, "The Importance of Climate Change Compared to Other Global Changes," in *Proceedings of the Second International Specialty Conference: Global Climate change, Crystal City, Virginia, October 13-16, 1998* (Sewickley, Pennsylvania: Air and Waste Management Association, 1998); Goklany, "Potential Consequences of Increasing Atmospheric CO_2 Concentrations Compared to Other Environmental Problems," *Technology* 7S (2000): 189-213.

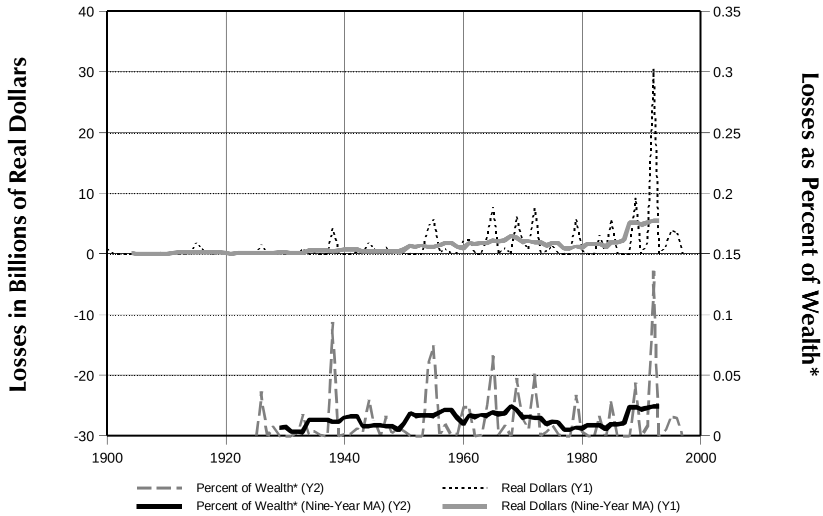
Thus, while global warming may be a serious problem in the long run, other environmental and health problems are likely to be much more urgent for the next several decades.[53]

Net Impacts of Aggressively Forcing the Pace of Greenhouse Gas Emission Reductions

Attempts to reduce greenhouse gas emissions beyond what could occur with secular trends in technology and the withdrawal of some subsidies for energy will come at a cost to the world's economic development. Even if GHG control requirements were restricted to developed countries, incomes would suffer in developing countries because trade between the two sets of countries is an important factor in maintaining and enhancing the latter's economic output. In 1995-97, exports came to 17.9 percent and 24.5 percent of the GDPs of the low- and medium- income countries, respectively.[54] The corresponding figures in 1990-92 were 14.2 and 21.7 percent, i.e., in the intervening five years, the share of GDP accounted for by exports

Figure 3

Hurricane Property Losses, 1903-1997



* Wealth measured as fixed reproducible tangible assets.

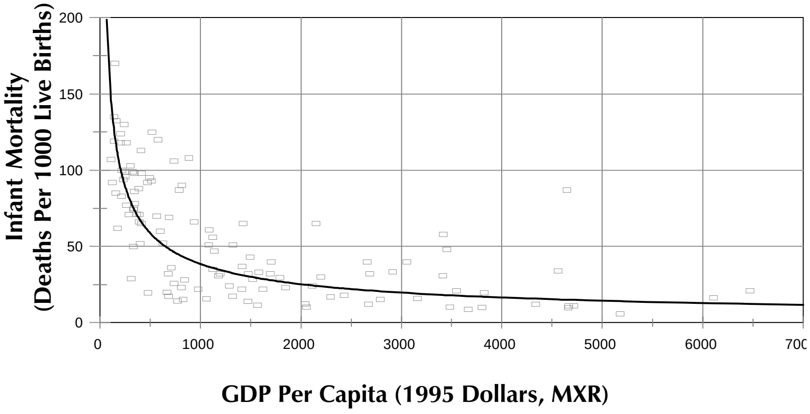
Sources: Indur M. Goklany, "The Importance of Climate Change Compared to Other Global Changes," in *Proceedings of the Second International Specialty Conference: Global Climate change, Crystal City, Virginia, October 13-16, 1998* (Sewickley, Pennsylvania: Air and Waste Management Association, 1998); Goklany, "Potential Consequences of Increasing Atmospheric CO_2 Concentrations Compared to Other Environmental Problems," *Technology* 7S (2000): 189-213.

rose 26 and 13 percent, respectively. The rise was even more rapid for the least-developed countries, which increased 37 percent (from 13.1 to 17.9 percent of GDP). An analysis done during the earlier period indicated that a 1 percent drop in the GDP of developed countries translated into a $60 billion loss in the exports of developing countries.[55] It would undoubtedly be a larger figure today if adjustments were made for increased trade and inflation.

When addressing the issue of economic development, it is critical to recognize that it is not an end in itself, but that it provides the means for numerous ends. Virtually every indicator of human well-being improves with the level of economic development.[56] As explained in the Appendix, economic development, which creates wealth, helps increase food supplies per capita (Figure A1 in the Appendix), which reduces hunger and malnutrition.[57] Economic development also makes basic public health services more available. Working together, improved health services and higher food supplies help reduce mortality rates. Thus, as levels of economic development increase, infant mortality rates decline (Figure 4)[58]

Figure 4

Infant Mortality vs. GDP Per Capita, 1997



Sources: Indur M. Goklany, *Economic Growth and the State of Humanity* (Bozeman, Montana: Political Economy Research Center, forthcoming), based on data from World Bank, *World Development Indicators*, CD-ROM (Washington, D.C.: World Bank, 1992).

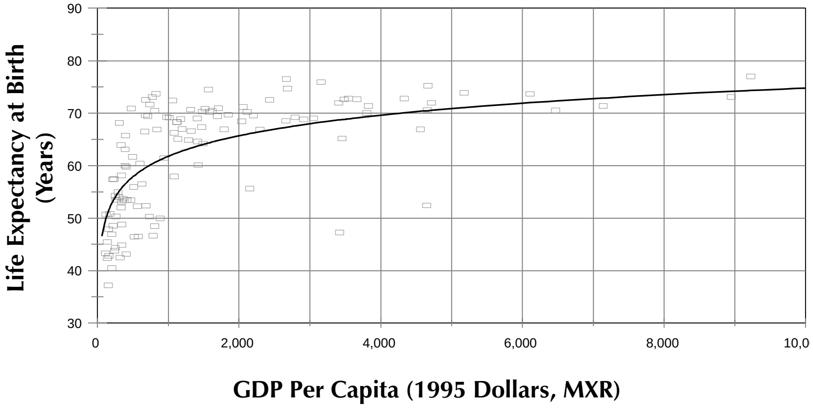
and life expectancies increase (Figure 5).[59] In each of these instances, improvements are most rapid at the lowest levels of economic development.[60] That is, a small decline in incomes in developing countries will have a larger negative impact than a similar drop for richer countries. Hence, aggressively forcing the pace of reductions will almost inevitably increase mortality rates and lower life expectancies, particularly in the developing countries.[61] These costs would be balanced, if at all, by the more speculative benefits associated with a reduction in the impacts of reduced warming, which, moreover, are more distant in time.

Reduced economic development has other downsides from the perspective of public health and environmental quality. First, lower levels of economic development are correlated with higher total fertility rates (see Figure A3 in the Appendix), which tends to push up population growth rates.[62]

Second, reduced economic development diminishes a society's adaptability to adversity in general and to climate change in particular.[63] This is because poorer societies have fewer resources available to research, develop, acquire, operate, and maintain technologies that would help society better cope with whatever problems it may be plagued with, including unmet public health, environmental, and social needs. Richer societies are, moreover, better able to afford higher levels of education that help create and maintain human capital. This human capital is a prerequisite for

Figure 5

Life Expectancy vs. GDP Per Capita, 1997



Sources: Indur M. Goklany, *Economic Growth and the State of Humanity* (Bozeman, Montana: Political Economy Research Center, forthcoming), based on data from World Bank, *World Development Indicators*, CD-ROM (Washington, D.C.: World Bank, 1992).

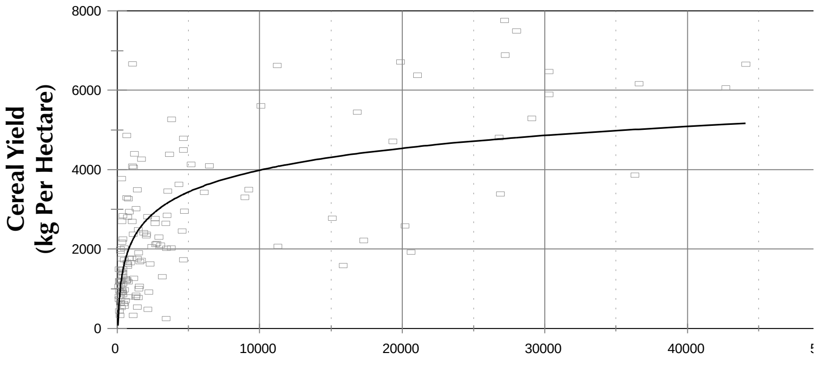
bringing about and implementing these beneficial changes in technologies.[64] Thus, it is no surprise that access to safe water and sanitation increases with the level of economic development. Figure A2 (see Appendix), for instance, shows that access to safe water increases with economic development and that improvement is most rapid at the lowest levels of development.[65]

As we have seen, future environmental and public health problems unrelated to climate change ought to substantially outweigh the adverse impacts of climate change for the next several decades. Thus, it would be counterproductive if, in the quest to make it easier to cope with the future adverse effects of climate change, we compromise the ability to cope with current public health and environmental problems that are more urgent today and are likely to remain so over the next few decades.[66]

Third, a poorer society has lower crop yields (see Figure 6 for cereals; also see the Appendix).[67] For any specific level of crop production, more habitat and forest land have to be converted to cropland to compensate for lower yields. This puts greater pressure on biodiversity and reduces carbon stores and sinks. In fact, such conversion is the major threat to global biodiversity.[68] It is hardly surprising that between 1980 and 1995, forest cover in developing countries decreased by 190 million hectares (Mha) while it increased 20 Mha in the developed countries.[69] Finally, efforts to substantially reduce GHG emissions could, over the next several decades,

Figure 6

Cereal Yield vs. GDP Per Capita, 1997



Sources: Data from World Bank, *World Development Indicators*, CD-ROM (Washington, D.C.: World Bank, 1992)

divert scarce resources from more urgent environmental and public health problems (see Table 1).

As an alternative to imposing additional GHG controls, energy prices could be increased through taxes or through elimination of subsidies. Such price increases, however, could have unintended consequences.

First, the productivity of the agriculture sector would be reduced because that sector is heavily dependent upon oil and gas for running its farm machinery, producing inputs such as fertilizers and pesticides, powering irrigation systems, and moving outputs from farms to markets. Thus, food production would decline and/or prices would rise. This is precisely what happened following the oil shocks of the 1970s.[70] In either case, food would be less accessible to those who are less well off, and hunger and malnutrition would increase, which, in turn, should increase rates of death and disease among those groups.

Second, an estimated 2.8 million people die annually because of indoor air pollution worldwide, mainly because of the burning of solid fuels (e.g., coal, wood, and dung) for heating and cooking in the home.[71] Increasing fossil fuel prices would only make it harder for households using solid fuels to switch to cleaner, commercial fossil fuels. Third, increasing fuel prices would inhibit the operation of heaters in the winter and air conditioners in the summer, which could lead to greater sickness, if not mortality, due to cold and heat waves.[72]

Applying the Precautionary Principle to Global Warming

The above analysis indicates that forcing the pace of greenhouse gas controls over the next several decades could indirectly aggravate hunger and reduce public health services, either of which, separately or together, could increase mortality, particularly in developing countries. On the other hand, such a policy might reduce the putative public health and environmental consequences of any global warming that may occur. The latter effect will probably be minor compared to the former, at least over the next several decades. Thus, the precautionary principle argues *against* accelerating GHG reductions for the next few decades beyond what would occur due to secular improvements in technology (i.e., normal measures to reduce air pollution and energy-related costs) and removal of unjustified subsidies for energy and land use.

This argument is strengthened by the immediacy criterion because the problems due to forcing the pace of GHG reductions are likely to occur sooner than the effects of deferring such reductions. The argument is further bolstered by the uncertainty criterion because the negative effects of greater poverty are also more certain than the positive effects of reducing climate change.

Similarly, with respect to environmental consequences, the threats to habitat, carbon stores and sinks, and biodiversity due to added GHG controls ought to outweigh the potential negative impacts of global warming over the next several decades. Moreover, any reduction in economic growth would make it that much harder to cope with adversities in general, whether they are connected to global warming or not.

Thus, there is no guarantee that forcing the pace of GHG controls will provide net global benefits for public health or, separately, for the environment, but there is a good likelihood that it may well worsen both. Therefore, one could argue that the precautionary principle requires that GHG reductions not be accelerated.

But there are counterarguments against deferring requirements to reduce GHG emissions.

First, given that the impacts of climate change could be in addition to other environmental stresses on natural and human systems, climate change may be the straw that breaks the camel's back. Consider malaria, for instance. Because of climate change, malaria incidences in 2100 may climb from 500 million to 550-580 million (Table 1).

But there are at least two ways to address the problem of the last straw.[73] The usual approach is to try to eliminate the last straw. This means trying to forestall climate change completely in order to wipe out the 50-80 million additional malaria cases projected for 2100. But we know that there will be some climate change even if atmospheric GHG concentrations could be stabilized immediately (a most unlikely occurrence).

Alternatively, we could lighten the overall burden on the camel's back by removing several other straws to make room for that proverbial last straw if and when it descends. This would also leave a margin for error. Accordingly, we could focus on reducing the total 550-580 million malaria cases that may occur in 2100 rather than concentrate only on the extra 50-80 million. If the baseline rate of 500 million is reduced by just 0.2 percent per year from now to 2100, that would more than compensate for any increase in malaria due to climate change. This strategy would likely provide more bang for the buck, and benefits to humanity will come sooner and more certainly. In effect, the first counterargument against deferring requirements for GHG controls is nullified by the adaptation and uncertainty criteria.

A second counterargument is that the assessment that the impacts of climate change will likely be relatively small is based on net global impacts. This assessment ignores the fact that there will be regional winners and regional losers because of non-uniform geographical impacts of warming. In particular, developing countries may be the biggest losers because being poor, they are the least able to adapt.

Consider food security, for example. Developing nations already run food deficits. Their net imports of grain currently amount to more than 10 percent of their production.[74] These deficits will get worse in the future because the increase in their food demand is expected to outstrip the increase in agricultural productivity.[75] Global warming is expected to further aggravate developing nations' food deficits, although developed countries' surpluses are expected to increase further. It is not necessary to require GHG reductions to address this issue, however. The potential increase in food deficits due to climate change can be addressed in exactly the same way as we address current imbalances in production (and differences in "comparative advantage") today, namely, through trade. Trade allows surpluses to flow voluntarily to deficit areas.[76] But to expand such trade, developing countries will need to "grow" the non-food sectors of their economies.[77] Also, as noted previously, economic growth has other ancillary benefits for human well-being. Thus, the second counterargument against aggressively forcing the pace of GHG controls is also invalidated by the adaptation criterion.

A third counterargument is that although climate change may not be the most urgent problem facing the globe over the next several decades, because of the inertia of the climate system, it may be too late to do anything about warming by the time its impacts become urgent. In other words, climate change may not be as urgent as other environmental problems today and tomorrow, but it could be crucial the day after tomorrow. Table 1, however, suggests that even if there is a 50-year lead time to implement climate change controls, we have two or three decades of leeway before commencing any costly control actions.[78] Moreover, as Table 1 indicates, even if we could solve the problem of climate change, most of the critical underlying problems that placed climate change on our agenda in the first place would still need to be addressed.[79]

Focus on fixing those current and urgent environmental problems that might be aggravated by climate change.

Consider forest and habitat losses. If human influence on climate change would be completely halted (an unlikely proposition), we could still lose 25 percent of global forest area because the increasing future human demand for food could increase pressures to convert additional habitat for agriculture (see Table 1).[80] Discounting for the moment the notion that climate change could increase global forest cover, as suggested by Table 1 and by the IPCC,[81] eliminating climate change would do little or nothing to reduce the major, imminent threats to global forests, ecosystems, biodiversity, and loss of carbon sinks and stores. Similarly, if human-induced climate change is eliminated, the challenge of adequately feeding the world's future population will be practically undiminished.

So how do we solve the urgent problems of today and tomorrow, without compromising our ability to address the climate change problems of the day after?

There are two complementary approaches to addressing these multiple problems. First, we can focus on fixing those current and urgent environmental problems that might be aggravated by climate change. With respect to the problem of increasing forest and habitat loss, for instance, this means addressing its basic causes, namely, the increased demand for land and water to meet human needs for food, clothing, shelter, paper, and other material goods. And to reduce such demand, we should attempt to produce as much food, timber, and other products per unit of land and water as is possible in an environmentally sound manner. This will also help solve the problem of food security because it will increase food production and help keep food prices in check. In addition, reductions in land conversion to agriculture would help maintain global carbon stocks and reservoirs, thereby mitigating carbon emissions. Also, by containing land costs, it would reduce costs for carbon sequestration or "energy" farms (to produce fuel wood for energy), if they are ever needed.[82]

To increase the productivity and efficiency of land and water use, we ought, for instance, to continue research and development on precision farming, integrated pest management, and methods to reduce post-harvest and end-use crop and timber losses. Greater emphasis should also be placed upon R&D to increase agricultural and forest productivity under less-than-optimal conditions, which might become more prevalent due to climate change, such as drought (due to higher temperatures and redistribution of precipitation), higher salinity (due to greater evaporation and saltwater intrusion in coastal agricultural areas), and higher carbon dioxide. Biotechnology, unless banned or greatly constrained, can play a crucial role.[83] Genetically modified crops could also limit environmental damage associated with agriculture by reducing reliance on synthetic fertilizers and pesticides that eventually pollute both soil and water, and by increasing no-till cultivation, which, in turn, would further reduce soil erosion, water pollution, and greenhouse gas emissions.[84]

The second approach to addressing the problems of today as well as those of the long term is to reduce the vulnerability of society in general by increasing its resilience to adversity, whatever its cause.[85] This can be accomplished by enhancing the mutually-reinforcing forces of technological change, economic growth, and trade. As noted, virtually every indicator of human or environmental well-being improves with wealth. Poorer countries are hungrier and more malnourished; their inhabitants suffer from higher mortality rates and live shorter lives (Figures 4 and 5). This is because they are less resilient and more vulnerable to any adversity owing to the fact that they have fewer resources (fiscal as well as human capital) to create, acquire, and operate new *and* existing-but-underutilized technologies to cope with that adversity. Just as someone suffering from AIDS is less immune to an infectious disease, no matter what the infection, so is a poorer society less immune to adversity, no matter what its proximate cause. And just as AZT boosts the entire immune system of a person with AIDS, helping that person combat any infection, economic growth boosts the ability of society to combat any adversity, and not just the adverse impacts of climate change.[86]

Reduce the vulnerability of society in general by increasing its resilience to adversity, whatever its cause....by enhancing the mutually-reinforcing forces of technological change, economic growth, and trade.

Economic growth enhances technological change, making society more resilient. In turn, technological change reinforces economic growth. Trade is also an integral part of boosting society's resilience. Not only does trade enable food and other natural resources to move from surplus to deficit areas voluntarily, but in so doing it also discourages exploitation of marginal resources, helps disseminate new technologies, and bolsters economic growth.[87]

To summarize, the precautionary principle argues for a cautious policy over the next few decades toward reducing GHG emissions; otherwise a more aggressive strategy could retard increases in global wealth, which could lead to greater hunger, poorer health, and higher mortality. Specifically, a comprehensive precautionary principle argues against forcing the pace of GHG controls. The principle argues, instead, for putting greater emphasis on research into the consequences of climate change, on solving current problems that may be worsened by climate change, and on enhancing society's adaptability and reducing its vulnerability to environmental problems by strengthening the institutions underpinning the mutually-reinforcing forces of technological change, economic growth, and trade. These reinforcing institutions include free markets, secure property rights, honest government, and predictable public policies.

In addition, enhancing adaptability and reducing vulnerability will raise the thresholds at which greenhouse gas concentrations become more "dangerous" and, in turn, would reduce the cost of GHG controls. The stated "ultimate objective" of the United Nations Framework Convention on Climate Change (UNFCCC) is to prevent anthropogenic climate change from becoming "dangerous," however that term may be defined.[88] Thus the approach outlined here is not only a "no-regrets" policy, but it would also be consistent with the requirements of the UNFCCC.[89]

Conclusion

The precautionary principle has been invoked to justify aggressive GHG emission controls. However, these justifications are based upon a selective application of the precautionary principle to a limited set of consequences. This justification ignores the probable, though indirect, impacts of a crash effort to significantly slow the increase in GHG atmospheric concentrations in the short to medium term. By slowing economic growth and/or increasing energy prices, such efforts could, in the final analysis, decrease overall access to food and delay improvements in public health. Poorer segments of society, especially in the developing world, would be most adversely affected. Thus, contrary to claims that a policy to reduce GHG emissions would be based on caution, such a policy would, in fact, increase overall risks to public health and the environment. In other words, the recommended policy cures may be worse than the underlying diseases, particularly for developing countries. This would be particularly ironic because one of the arguments for taking aggressive steps to reduce human-impacts climate change is that its effects would be worse for developing countries who cannot afford adaptive measures and technologies.

Contrary to claims that a policy to reduce greenhouse gas emissions would be based on caution, such a policy would, in fact, increase overall risks to public health and the environment.

The precautionary principle, properly applied, with full consideration of all the public health and environmental consequences of action and inaction, argues for substantially different policies. Specifically, the precautionary principle argues *against* GHG emission reduction requirements in the next few decades if they go beyond secular improvements in technology and elimination of unjustified energy subsidies. Aggressive GHG controls are likely to retard economic development, which would lead to greater hunger, poorer health, and higher mortality for human beings. Moreover, oil and gas prices ought not to be raised because that would reduce food availability, as well as slow down the abandonment of solid fuels for heating and cooking in the developing world, thus delaying reductions in mortality from indoor air pollution. Such requirements could also reduce crop yields and increase land conversion, habitat loss, and threats to biodiversity.

The precautionary principle argues, instead, for first placing a much higher priority on directly solving current problems that may be aggravated by climate change. If we are truly concerned about malaria or malnutrition, we should expend our scarce resources (human and capital) to address these problems today. Addressing climate change today, if it does any good at all, won't produce benefits for several decades. Second, the precautionary principle would also support increasing society's adaptability and decreasing its vulnerability to environmental problems in general and climate change in particular. These objectives could be achieved by bolstering the institutions that are the foundations of the mutually-reinforcing forces of technological change, economic growth, and trade. These institutions include free markets; secure property rights; honest bureaucracies and governments; and predictable public policies. Moreover, consistent with the precautionary principle and the UNFCCC's "ultimate objective," enhancing adaptability and reducing vulnerability will raise the thresholds at which greenhouse gas concentrations become "dangerous." These efforts would also reduce the overall cost of whatever controls may be ultimately necessary.

It has been suggested that we view aggressive pursuit of GHG emissions as a form of insurance. But, as shown above, the world cannot afford the premium for this particular policy. It would make little sense for a family to purchase an insurance policy with a premium that might preclude the breadwinner from putting gas in the tank in order to go to the job needed to keep the family clothed, fed, and sheltered. On the other hand, the truly precautionary policies suggested in this paper would help humanity continue to progress while limiting the displacement of the rest of nature. These policies would also allow humanity to address the urgent problems of today and tomorrow without compromising the ability to deal with future problems, whether due to climate change or some other agency.

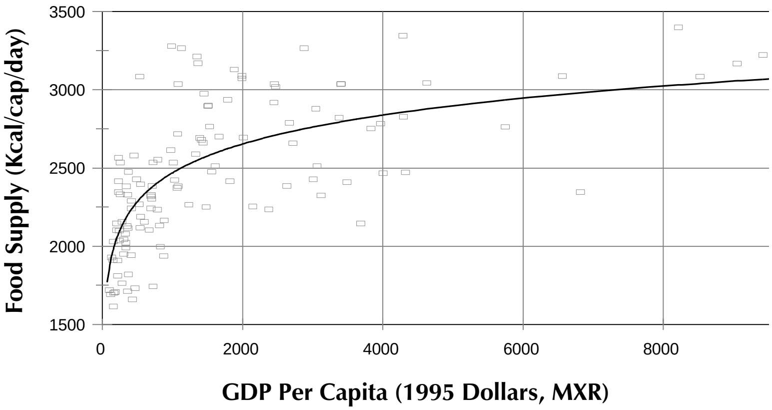
Appendix

In this Appendix, I present some salient results drawn from various investigations into the relationship between economic development and environmental and human well-being that are summarized in two forthcoming reports, *Economic Growth and the State of Humanity* and *The Effects of Economic Growth and Technological Change on the Environment*. These investigations indicate that restricting economic development will, sooner or later, be problematic for the environment as well as for human well-being, particularly in developing countries because, ultimately, richer is cleaner, healthier, longer-lived, and less susceptible to adversity. As noted, economic development is not an end in itself, but it provides the means for numerous ends. Virtually every indicator of environmental and human well-being sooner or later improves with the level of economic development. Crop yields increase with the level of economic development because richer countries can afford the technologies and the inputs needed to increase productivity (see Figure 6). If, despite higher yields, they run food deficits, then the richer countries can obtain more food on the open market through trade. Thus, one way or another, available food supplies per capita increase with wealth (Figure A1),[a] which then reduces hunger and malnutrition—the first step to better health. Moreover, economic development makes basic public health services (e.g., access to vaccinations, safe water, and sanitation) more available. This is illustrated in Figure A2, which shows access to safe water increasing with the level of economic development.[b] Greater wealth, better nutrition, more affordable medicine, and greater access to health services combine to reduce mortality rates and increase life expectancies (see Figures 4 and 5 in the text). Lowering the infant mortality rate helps create one of the basic conditions for families wanting to limit the number of their offspring. Education, particularly of women, also helps lower the desire for a larger family. But literacy as well as the level of education also go up with wealth. For these and other reasons, lower total fertility rates (a critical determinant of birth rates) are associated with higher levels of economic development (Figure A3).[c] Ultimately, this provides an environmental bonus since it helps limit human demands on land and water and helps reduce greenhouse gas emissions.

Note that in each of the figures, improvements are most rapid at the lowest levels of economic development.

Figure A1

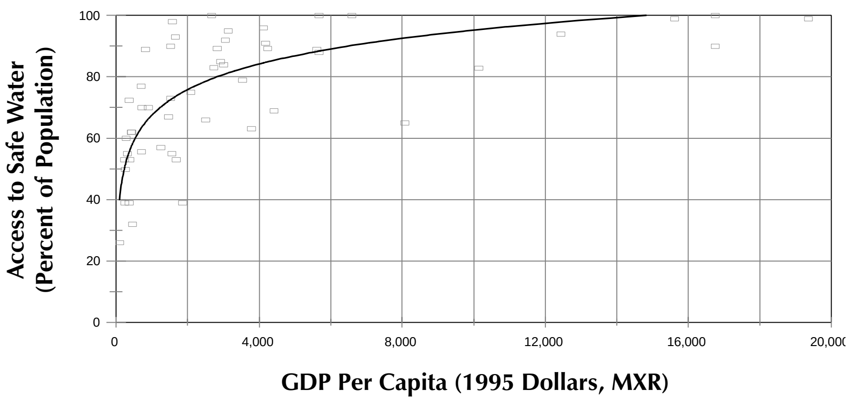
Food Supply vs. GDP Per Capita, 1994



Source: Goklany, *Economic Growth and the State of Humanity*, and references therein.

Figure A2

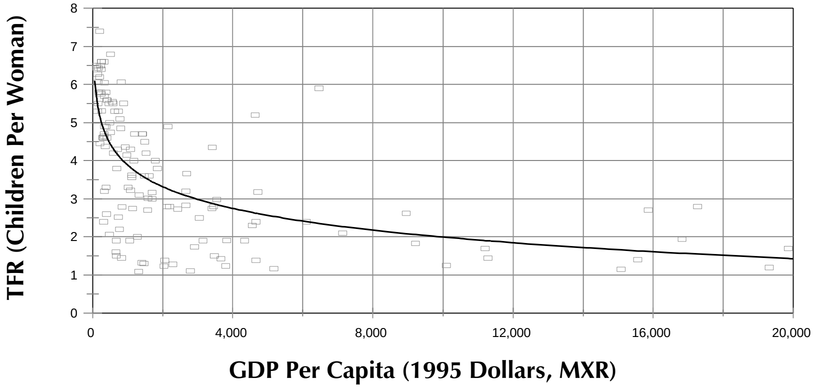
Access to Safe Water vs. GDP Per Capita, 1995



Source: Goklany, *Economic Growth and the State of Humanity*, and references therein.

Figure A3

Total Fertility Rate vs. GDP Per Capita, 1997



Source: Goklany, *The Effects of Economic Growth and Technological Change on the Environment*, based on data from World Bank, *World Development Indicators*.

Notes

1. "Full Text of the Convention," Article 3, Paragraph 3, *United Nations Framework Convention on Climate Change,* n.d., <http://www.unfccc.de/resource/conv/conv_005.html>.
2. This formulation does not necessarily call for the framework to be quantitative.
3. "No regrets" actions are those that ought to be undertaken on their own merits, unrelated to any benefits related to global warming.
4. "Summary for Policymakers: The Economic and Social Dimensions of Climate Change, IPCC Working Group III," Intergovernmental Panel on Climate Change, n.d., <http://www.ipcc.ch/pub/sarsum3.htm>.
5. John S. Perry, "Climate Change—The Potential for Surprises," *Journal of the Federation of American Scientists* 52, no. 4 (July/August 1999), <http://www.fas.org/faspir/V52N4.htm>.
6. In general, these secular improvements are driven by energy consumers' desire to reduce their costs and improve their local and personal environment, and society's desire to limit the public health impacts of traditional air pollutants. See Indur M. Goklany, *Clearing the Air* (Washington, D.C.: Cato Institute, 1999).
7. Carolyn Raffensperger, Joel Tickner, and Wes Jackson, eds., *Protecting Public Health and the Environment: Implementing the Precautionary Principle* (Washington, D.C.: Island Press, 1999).
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9. See Jonathan Adler et al., *Greenhouse Policy without Regrets* (Washington, D.C.: Competitive Enterprise Institute, 2000); Frank B. Cross, *Could Kyoto Kill? The Mortality Costs of Climate Policies* (Washington, D.C.: Competitive Enterprise Institute, 1998); Indur M. Goklany, "Applying the Precautionary Principle in a Broader Context," in *Rethinking Risk and the Precautionary Principle*, Julian Morris, ed., (Oxford, England: Butterworth-Heinemann, 2000).
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Notes to the Appendix

a. The curve in Figure A1 is fitted using a log-linear model. In this and subsequent figures, GDP per capita (or per capita income) is in 1995 U.S. dollars using the market exchange rate (MXR). N=150 and R^2=0.63. The slope is significant at the 0.001 level. The scale on the x-axis is cut off at a GDP per capita of $10,000 to better illustrate the rapid change in available food supplies per capita per day at low levels of per capita income. The y-axis scale commences at 1,500 kcals per capita day in recognition of the fact that the minimum energy needed by the body to perform basic activities at rest in a supine position is in the general range of 1,300 to 1,700 kcals/ day for adults with different characteristics (i.e. age, sex, height, body weight). See Goklany, *Economic Growth and the State of Humanity*, and references therein.

b. Goklany, *Economic Growth and the State of Humanity*, based on data from World Bank, *World Development Indicators*. N is 51. Because a number of countries were already at 100 percent in 1995, a Tobit model was used for truncation at that level. The untruncated log-linear regression had R^2 of 0.55. The slope is significant at the 0.001 level. This figure presents the data up to $20,000.

c. Figure A3 is fitted using a log-linear relationship. N and R^2 are 148 and 0.55, respectively. The slope is significant at the 0.001 level. The x-axis scale is cut off at $20,000 per capita. See Goklany, *Effects of Economic Growth and Technological Change on the Environment*, and references therein.

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