An Economist's Perspective on Climate Change and the Kyoto Protocol

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0. Introduction

I have spent many years trying to figure out what is the optimal climate change policy for Canada. I believe the answer is, roughly, "keep studying the basics, don't try to stop it and learn to adapt." But one does not come to this view with reference to economics alone. So in my discussion today I will try to give a snapshot of some of the range of technical issues that I have tried to think through in pursuit of an optimal climate policy.

There are no intellectual shortcuts on this issue. Even a simple question like "what is the cost of Kyoto" turns out to be maddeningly difficult to answer. Kyoto is, at best, a target: the costs are attached to the specific policies that will be used to reach that target, and to date no one knows what those policies will be for Canada. Broadening the issue to ask "what is the cost of climate change for Canada?" only piles up the ambiguity. There is no formal definition of "climate," only traditional rules based on rather ad hoc averages of geophysical data, the sampling of which is often very unsystematic. There is even less agreement on what constitutes "change," which is why every time a forest burns or an iceberg calves someone asks: "Is this a sign of global warming?" Witness the apocalyptic thrill as seers and sages scan the skies for signs, omens and portents of global warming; but climate change is an elusive concept, and no one is sure what the thing would look like, even if it was already happening.

This ambiguity is reflected in the two key documents that govern much of the thinking on this issue. The 1992 UN Framework Convention on Climate Change (UNFCCC) defined "climate change" as follows:

> "Climate change" means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.
>
> (http://unfccc.int/index.html)

The recent Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) defined it differently (http://www.ipcc.ch/):

> 1 *Climate change* in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity.

This is a very important difference: The IPCC is looking for signs of any change, whereas the policy instruments prescribed by the UNFCCC are not triggered unless it is a particular kind of change: that attributable to human activity. When IPCC officials declare that "climate change" is for real, this is about as informative as announcing that the passage of time is for real. Of course the climate changes: if it didn't Winnipeg would still be under a glacier. But the fact that the last ice age ended doesn't imply that the policy mechanisms of the UNFCCC should kick in. That's the problem with the ambiguity over the term "climate change"—and it seems to trip up a lot of people—accepting the reality of "climate change" does not mean accepting the need for policy interventions. And denying that global warming is a problem requiring costly policy measures is not the same as denying "climate change."

This purported link between two fundamentally different concepts was written into those pamphlets Environment Canada sent out two years ago. They began, ominously, "Our Climate is Changing" and concluded with the stuff on the back about the importance of turning down your thermostat and doing the laundry in cold water. It's always comforting when big, complicated issues turn out to have such simple solutions, so perhaps we should take our cue from this line of thinking.

Therefore, rather than start with one of the complicated, ambiguous questions posed above I will organize my presentation around the practical question, "Does the possibility of climate change imply that I should wash my socks in cold water?" The affirmative answer offered by the Government of Canada arises from a long chain of assertions like this:

1. The "climate" is a well-defined thing, the mean state of which is measured with precision.
2. The equations of motion of the climate are sufficiently-well understood that the full range of natural variability is quantified and future climate states can be predicted.
3. By adding to the stock of atmospheric CO_2 humans have an affect on the climate which necessarily involves a general warming of the Earth's surface.
4. The present state of the climate can only be explained by invoking this mechanism.
5. Continued use of fossil fuels, by adding CO_2 to the air, will cause unprecedented changes to the future climate.
6. These changes will be generally deleterious.
7. We ought to reduce emissions of CO_2.
8. The best mechanism to accomplish this is through the Kyoto Protocol.
9. The best way for Canada to comply with Kyoto is to pursue a package of measures as outlined in the Canadian Climate Change Plan, which includes encouraging Canadians to do their laundry in cold water.

To the extent time permits I will grapple with each of these assertions. Notwithstanding the simplicity of the solution proffered in #9 I find the chain of thinking problematic at each step.

1. The "climate" is a well-defined thing, the mean state of which is measured with precision.

"It's sunny out" is a statement about the weather. "Palm trees do not grow in Winnipeg" is a statement about the climate. *Climate* is a rather abstract concept that stands behind the weather. Dictionaries define it with phrases like "prevailing conditions" and "averages over some period of time" and so forth. Linacre (1992) surveyed 16 published definitions and reduced them to the following:

"Climate is the synthesis of atmospheric conditions characteristic of a particular place in the long-term. It is expressed by means of averages of the various elements of weather, and also by the probabilities of other conditions, including extreme values."

Note the ambiguities: Does 'long-term' in a geophysical setting mean 5 years? 30 years? 300 years? What are the 'various elements' and how do they average together? For example how would one average warm and wet, then compare it to the average of cold and dry?

Very well, it's vague: so is 'the economy.' We don't need to have a precise definition of 'economy' to study it, so we shouldn't impose undue burdens on other fields. We can work with averages and aggregates in economics without doing too much violence to theoretical consistency (usually). But in the case of thermodynamic phenomena there is a catch, which as far as I know has not been discussed in the context of climate change before Chris Essex and I wrote *Taken By Storm*.

The catch does not involve a novel, contentious or obscure theory; it involves an old, standard, well-known definition from introductory thermodynamics. Indeed it seems to have been overlooked precisely because it is so elementary. The main problem in the debate over what the Global Temperature is doing is that there is no such thing as a Global Temperature. Temperature is a continuous *field*, not a scalar, and there is no physics to guide reducing this field to a scalar, by averaging or any other method. Consequently the common practice of climate measurement is an ad hoc approximation of a non-existent quantity. Figure 1 shows NASA's version of this simulacrum.

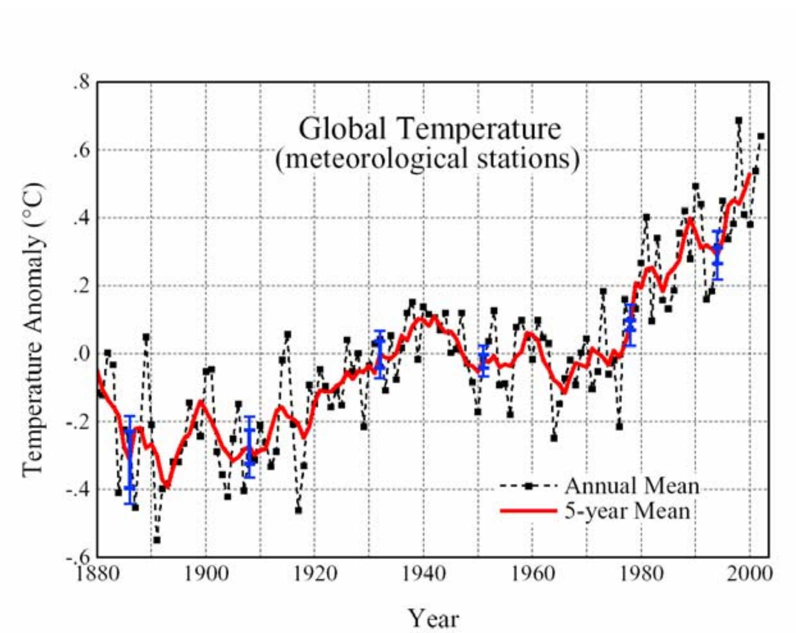

Figure 1. The "Global Temperature" from http://www.giss.nasa.gov/data/update/gistemp/graphs/.

Even if climate scientists were willing to use one arbitrary average and call it the "Global Temperature," they also face the acute problem of sampling. Meteorological services use a 30-year interval to define "normals" for temperature. These are not "normal" temperatures, the name notwithstanding, they are just averages. On a geological scale the "normal" for Winnipeg would be that of the interior of a glacier. Why don't we use, say, 300 years? The answer is the data do not exist. But this does not provide scientific justification for defining 'climate' as a 30-year average.

Equally problematic is the collapse that occurred around 1990 in the number of climate monitoring stations around the world. Figure 2 (Peterson and Vose 1997) shows the numbers for the Global Historical Climatology Network (GHCN), graphed in terms of the number of stations with at least 10 years of reliable data (a) and the corresponding geographical coverage (b). In the early 1990s, the collapse of the Soviet Union and the budget cuts in many OECD economies led to a sudden sharp drop in the number of active weather stations.

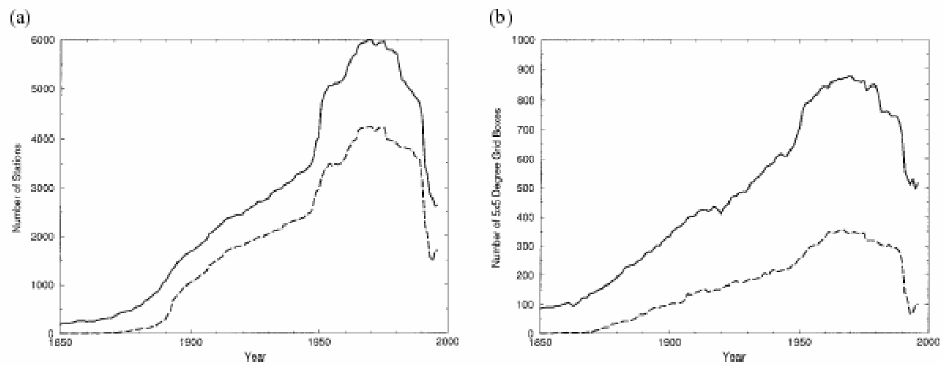

FIG. 2. Time series of the number of stations (a) and the number of $5° \times 5°$ boxes (b) for mean temperature (solid) and maximum and minimum temperature (dashed). The graphs start in 1850, but the earliest mean temperature datum is for January 1701 from Berlin, Germany, and the earliest mean maximum and minimum temperature data in GHCN are for March 1840 from Toronto, Canada. The reasons why the number of stations in GHCN drop off in recent years are because some of GHCN's source datasets are retroactive data compilations (e.g., World Weather Records) and other data sources were created or exchanged years ago. Only three data sources are available in near-real time. The rise in maximum and minimum temperature stations and grid boxes in 1995 and 1996 is due to the World Meteorological Organization's initiation of international exchange of monthly CLIMAT maximum and minimum temperature data over the Global Telecommunications System in November 1994.

Figure 2: From Peterson and Vose (1997).

Figure 3 shows the total number of stations in the GHCN and the raw (arithmetic) average of temperatures for those stations. Notice that at the same time as the number of stations takes a dive (around 1990) the average temperature (red bars) jumps. This is due, at least in part, to the disproportionate loss of stations in remote and rural locations, as opposed to places like airports and urban areas where it gets warmer over time because of the build-up of the urban environment.

This poses a problem for users of the data. Someone has to come up with an algorithm for deciding how much of the change in average temperature post-1990 is due to an actual change in the climate and how much is due to the change in the sample. When we hear over and over about records being set after 1990 in observed "global temperatures" this might mean the climate has changed, or it means an inadequate adjustment is being used, and there is no formal way to decide between these.

Nevertheless, confident assertions are routinely made about 'changes in the global temperature' on the order of tenths of a degree C per decade. The confidence masks pervasive uncertainty in the underlying concepts and data quality.

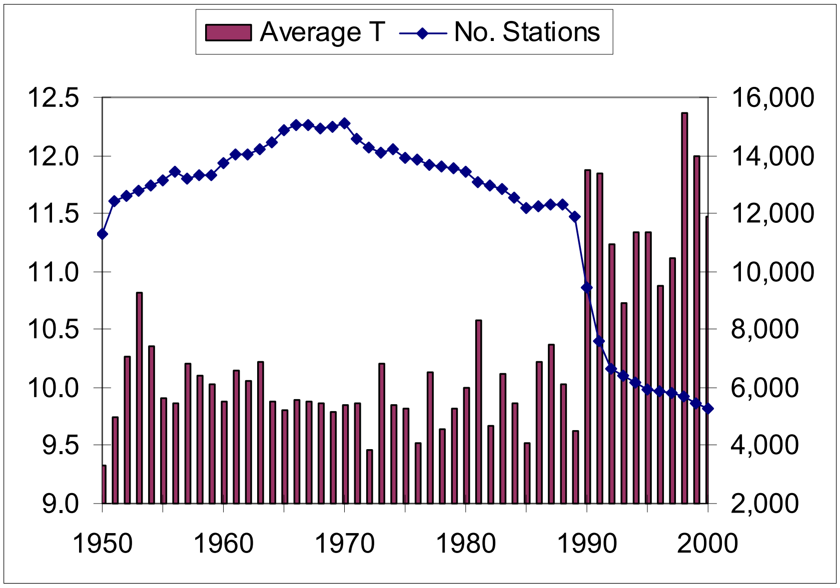

Figure 3. Number of stations in GHCN collection (diamonds, right axis); Average temperature of annual sample (bars, left axis in C). Source: see *Taken By Storm* chapter 4.

This discussion only looked at temperature. If we look at precipitation, humidity, air pressure and so forth the situation only gets worse. Ad hoc averaging rules, inconsistent sampling and a lack of theoretical guidance as to how to define and interpret the basic quantities pervade the topic and consequently I am very skeptical about our ability to define and measure "climate" of the Earth with the sort of precision we expect in a medical thermometer.

2. The equations of motion of the climate are sufficiently-well understood that the full range of natural variability is quantified and future climate states can be predicted.

There is no theory of climate. This is an overlooked but elementary point Chris Essex and I tried to reinsert into the climate discussion. By 'theory' I mean a set of known equations representing laws of nature. There is a theory of how atoms and molecules behave: that is, there are differential equations that can be written down and used for predicting things. Average up from them to the everyday level we experience and you find a theory also exists for describing the behaviour of fluids (it's called Navier-Stokes theory). The theory can be derived by the averaging-up process, but conveniently it was already known before this approach was undertaken, so the path was well-marked. Also, experimental data are available to guide the theorizing. So this aspect of the scientific work went ahead with the intellectual odds in its favour, and nonetheless it was very hard.

Now think about the next step: averaging up to a theory that describes air and water motions on the scale of climate—time scales of decades or centuries and spatial scales of regions and continents. We are used to seeing numbers like "annual average temperature." But remember, we *compute* these things, we do not *observe* them. Nature does not work with annual averages. Nature integrates temperature over time, but in different ways in different materials, over different time scales. The growth and decline of glaciers represents a local "averaging" of temperature and precipitation, as does the migration of the northern tree line in a particular region. The appropriate time scale, be it annual, decadal or some other, is up to nature herself, and is not determined by what we find convenient for organizing our data.

If we make the heroic assumption that we can define climate as a 30-year average of local temperatures, we can then ask: what are the equations of motion that describe the evolution of this average over, say, the open ocean or the Rocky Mountains? The answer is no one knows. In principle they are deterministic but it is unlikely we will live to see them derived. The base equations (Navier-Stokes) for the climb to a climate theory are insoluble. They cannot be rearranged into a form useable for direct numerical computations nor can they be solved into a form useable for the kind of averaging needed to analyze on the climate scale. So when contemplating the derivation of a theory of climate, all the advantages that got us to a theory of fluids are lost. The end point is not known. Experiments are impossible. And the base equations are insoluble.

It gets worse. The study of fluid dynamics in meteorology gave rise to the rich and remarkable field of chaos theory. Most of us by now have a basic understanding of chaotic systems, including the property that they are bounded yet sensitive to arbitrarily small changes in initial conditions. Chaotic systems can be algebraically very simple. For instance, the logistic map, $X_t = aX_{t-1}(1-X_{t-1})$, is chaotic for initial values of X between 0 and 1, and values of a around 3.8. Introduce chaos into a mathematical system and predictability quickly vanishes. This is true even in deterministic chaotic systems. It is why weather forecasts will never get much more reliable than they are now, regardless of how big or fast our computers get: because the weather is chaotic.

Is the climate chaotic? You would think this would be a question of great interest to the Intergovernental Panel on Climate Change, for it defines the limits to their useful prediction horizon. And indeed they have expressed a view. They accept that the climate *is* chaotic and consequently future climate states cannot be predicted:

> In climate research and modeling, we should recognize that we are dealing with a coupled non-linear chaotic system, and therefore that the long-term prediction of future climate states is not possible. The most we can expect to achieve is the prediction of the probability distribution of the system's future possible states by the generation of ensembles of model solutions.

IPCC Third Assessment Report, Chapter 14.2.2.2

This is a remarkable admission. It is typical of the IPCC that it gets buried in the back of a thousand page report, while the hubristic declarations of confidence in model forecasts are all over the Executive Summary.

Chaos draws a veil of unknowability across the future, as does the phenomenon of random walks, something that economists have learned (though not, perhaps, those in business schools?). In the case of temperature the situation is even worse than in economics, since the climate is chaotic *and* the famous average temperature statistics appear to be random walks (Essex 1987, Kärner 2003, 1996; Tsonis *et. al.* 1998).

The IPCC does not use the term 'prediction' to describe its divination of future climates. Instead it refers to "projections" based on "scenarios." This is a tacit admission of the reality that no one can predict the climate of the future, though the wording is weasely because they turn around and sell their predictions to unsuspecting cabinet ministers anyway.

Since experiments in climate are impossible and there is no theory of the system's evolution, scientists are limited to studying sparse observations, working up ad hoc statistics and using parameterized models. It is reminiscent of macroeconomics in the 1960s and 1970s. Climate modelers will probably go through their own Lucas critique, and it will probably be as tumultuous for them as it was for macroeconomists.

Meanwhile, inability to predict the behaviour of the climate, combined with a lack of an observational base implies incomplete understanding of it. The physical behaviour of climate is an open research question. It is contradictory to acknowledge that we cannot predict its behaviour nor can we measure its mean state precisely, then say we can characterize its natural variability so precisely that comparatively minuscule changes can be attributed to anthropogenic factors. For more on this I refer you to Chapters 6 and 7 of *Taken By Storm*.

3. By adding to the stock of atmospheric CO_2 humans have an affect on the climate which necessarily involves a general warming of the Earth's surface.

The problem with this assertion is the word "necessarily." It ain't necessarily so. What the 'certainty' crowd have in mind is the radiation mechanism in a greenhouse. That is, by any reckoning, simple, settled and certain. Calling the atmosphere a "Greenhouse" (as, among many others, Environment Canada does, see http://www.climatechange.gc.ca/english/workroom/students/greenhouse.shtml) hides all the complexities of fluid dynamics and thereby sweeps aside what makes the issue complicated. Chris and I treat these topics in detail in Chapter 3 of TBS, but here's a sketch.

Figure 4 shows a stylized picture of solar radiation coming down, then the offsetting energy flow from the Earth's surface. There are two principal mechanism for energy transport back to space: radiation and fluid dynamics. Radiation means the low-frequency infrared shine that comes off the land and water. Fluid dynamics refers to the convection of air and water in the atmosphere that constitutes our weather. They each drain about half the energy from the surface, though the proportions change with altitude. The amount of convection decreases through the stratosphere and at the top of the atmosphere all energy drain is radiative.

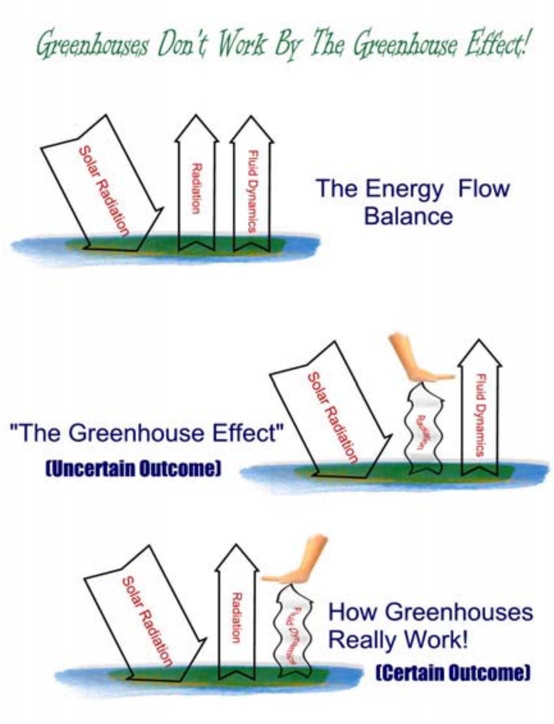

Figure 4: Radiative and Convective Energy Transport.

A greenhouse works according to the bottom picture. By putting up glass or plastic the fluid dynamics (i.e. air currents) are blocked, so the radiation has to intensify to maintain an equivalent energy drain. The radiative transfer equation is a linear ordinary differential equation in which temperature appears as an absolute level. The solution can be computed and it is known unambiguously that the greenhouse has to warm up. This can be confirmed experimentally too, of course.

The so-called "Greenhouse effect" works according to the middle picture. CO_2 filters infrared light in a narrow band around 15 microns. Water vapour does almost all the infrared absorption in the atmosphere, but CO_2 does a little. So adding CO_2 to the air slows the radiative energy drain. The fluid dynamic has to intensify to accommodate. But this process is governed by a nonlinear vector partial differential equation, which has no known solution and cannot be directly computed. Temperature does not appear as an absolute quantity in those equations, only as a gradient. It is impossible to predict what temperature will do in this context. Essex (1992) showed that within the known range of variability of key climate model parameters it is possible to predict CO_2-induced cooling at the surface, without violating the laws of physics. The fact that models predict (sorry, 'project') warming only reflects the fact that they are parameterized to do so.

The role of CO_2 in warming the atmosphere is very minor. On its own CO_2 could not generate a climate change. Everything depends on the water vapour feedback, since H_2O is the main 'greenhouse' gas, absorbing across most of the infrared spectrum. So a major scientific challenge for climate modelers has been to characterize the way water vapour in the atmosphere adjusts to the minuscule changes arising from CO_2 enrichment. But this involves all the fatal complexities of fluid dynamics, including chaos and the unsolved problem of turbulence. The uncertainties are important and fundamental and will not be resolved any time soon.

4. The present state of the climate can only be explained by invoking this mechanism.

At some point in the past, the state of the climate—however measured—could be entirely explained by natural causes. But it is now routinely asserted that the present state can only be explained by invoking the influence of infrared-absorbing gases. The draft report of the Intergovernmental Panel on Climate Change released at the end of scientific review (April 2000) hinted at this:

> • *From the body of evidence since IPCC (1996), we conclude that there has been a discernible human influence on global climate.* Studies are beginning to separate the contributions to observed climate change attributable to individual external influences, both anthropogenic and natural. This work suggests that anthropogenic greenhouse gases are a substantial contributor to the observed warming, especially over the past 30 years. However, the accuracy of these estimates continues to be limited by uncertainties in estimates of internal variability, natural and anthropogenic forcing, and the climate response to external forcing.

However the final version published 9 months later (IPCC 2001) was much more definitive:

> In the light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely[7] to have been due to the increase in greenhouse gas concentrations.

There was no great advance of science in those 9 months to justify this change in wording: some officials (never identified) simply wanted to make a stronger statement. The whole business of detecting an anthropogenic influence merits scrutiny, but I'll just reiterate some points already made and refer you to TBS chapter 6 for details.

The state of the climate cannot be measured in precise, quantitative units. The natural mechanisms of change have not been characterized above a low-level of understanding, and to the extent that we understand them they appear chaotic and formally unpredictable. The effect of CO_2 on the atmosphere is not predictable, even in principle. In this context, the claim that some climate modelers have unambiguously detected the influence of man on the global climate strikes me as nonsensical.

A more formal evaluation of the role of CO_2 was published recently in the *Journal of Geophysical Research* by Olavi Kärner (2003), a statistician at the Tartü Observatory in Estonia. Kärner's insight was that if CO_2 is the dominant forcing mechanism on atmospheric temperatures (as the IPCC has asserted), and the CO_2 concentration is monotonically increasing, there should be a spectral signature in temperature data called "persistency." Persistency means that if a series departs in one direction over a particular time span it tends to move in that same direction over subsequent periods of the same scale. Antipersistency means that a departure in one direction over some scale is followed by a move in the opposite direction over the subsequent period of the same scale. Persistency can be quantified by looking at the power spectrum of a series, an in particular by looking at the Hurst exponent of a power function. If the Hurst exponent is between 0 and 0.5 the series displays antipersistency and if it is between 0.5 and 1 the series displays persistency.

Kärner had run a spectral analysis on the daily solar irradiance series from space-based radiometers and found the Hurst exponent was between 0.22 and 0.35, implying antipersistency. This gave rise to a rather neat hypothesis test. If solar irradiance dominates the climate mechanism the temperature data will have a Hurst exponent below 0.5; but if CO_2 is dominant the exponent will be over 0.5. So he looked at 22 years' worth of daily temperature readings from NASA's polar-orbiting weather satellites and found their Hurst exponent is between 0.26 and 0.36: closely matching the solar pattern and contradicting the CO_2-forcing mechanism. His conclusion was:

> "[The] solar forcing variability is actually the governing one among other existing (random or not) forcings in the Earth climate system…The revealed antipersistence in the lower tropospheric temperature increments does not support the science of global warming developed by IPCC… Dominating negative feedback also shows that the period for CO_2 induced climate change has not started during the last 22 years. Increasing concentration of greenhouse gases in the Earth atmosphere appeared to produce too weak forcing to dominate in the Earth climate system."

The only comment I would add here is that it is highly unlikely Kärner's work will influence the IPCC. It has been observed by others that from report to report the evidence changes but never the conclusions. The conclusions of the next one, the Fourth Assessment Report, are foregone from the outset. This sort of finding will, at best, be grudgingly acknowledged in a footnote somewhere, buried amidst pages of full-colour graphics of model-generated warming projections.

5. Continued use of fossil fuels, by adding CO_2 to the air, will cause unprecedented changes to the future climate.

We have so little capacity to measure the state of the climate today, it is even less likely we can measure the state of the climate as at Thursday October 23, 1503. Pretending that the job gets easier if all you are interested in are vague averages 'round about' 1503-ish runs into the problem mentioned above that there is no physical rule for averaging the temperature field. Nonetheless there are people going around today claiming that a 'robust scientific consensus' (to use the words of one group's statement) exists that the climate is changing today in ways unprecedented since the end of the last ice age, and that Global Temperatures are higher today than they have been for the past thousand years, or more.

I have an unexpected familiarity with Mann's work now, having misspent my fall sabbatical on a research project with Steve McIntyre on the subject (McIntyre and McKitrick 2003). It began as an audit of Mann's paleoclimate proxy data base and ended up being shown around the US Senate as part of a debate on the McCain-Lieberman climate bill.

Mann and his coauthors (1998) published a famous graph (Figure 5, top) which suggests that the late 20th century climate is unusually 'warm' compared to that of the previous 600 years. In subsequent work he went on to extend the claim back to AD1000 and most recently to 0 AD.

Steven McIntyre obtained Mann's data from him in late 2002 and undertook what was apparently the first due diligence audit. In the end he and I found nine types of errors in the data. Some were careless collation errors, others involved using incomplete or obsolete versions of source data, and some were computational errors involving principal component series. We constructed a new data base using Mann's specified sources and repeated his statistical analysis method on it. Simply correcting his data errors ended up radically-overturning his results.

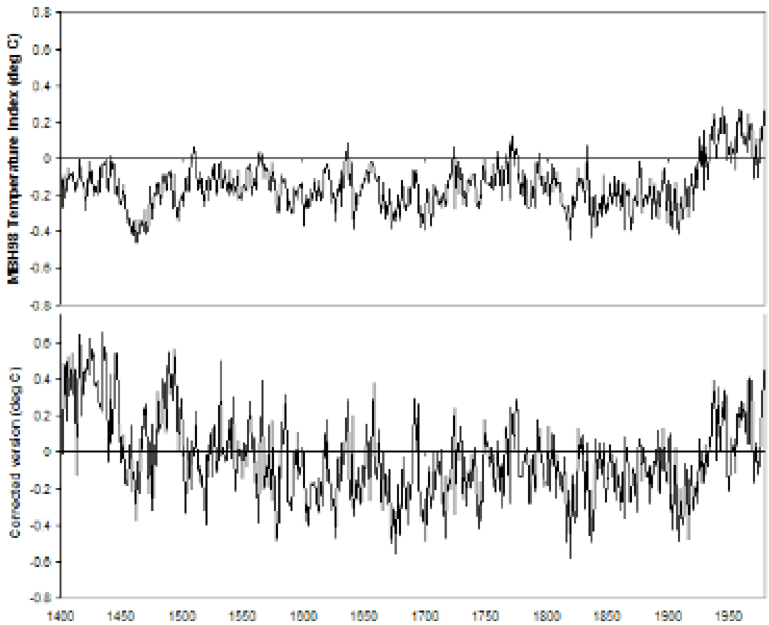

Figure 5. The Northern Hemisphere Temperature Index: original (top) and corrected (bottom)
Source: McIntyre and McKitrick 2003.

As shown in Figure 5, if the height of the graph is interpreted in the common way, as an index of the "warmth" of the northern hemisphere climate, then the hockey stick-shaped IPCC version (top) is merely an artifact of substandard data management and miscalculated principal components. The corrected version (bottom) shows that the late 20th century exhibits neither unusual mean values nor variability.

This is important since the 20th century has been a period of apparently unusual build-up of CO_2 in the atmosphere. I say "apparently" since there is good evidence from the examination of tree leaves preserved in northern European bogs that CO_2 levels in the air went through rapid growth and decline after the end of the last ice age (see *Taken By Storm* chapter 7). But most of the recent build-up happened after 1950, where the temperature lines in Figure 5 go flat, and certainly did not occur in the 15th century to coincide with the rapid swings in that portion of the graph.

Evidence of substantial climate variability in the past millennium (see survey in Soon and Baliunas 2003), the fact that attribution of climate change to CO_2 is done using a method that presupposes the veracity of general circulation models (see *Taken By Storm* chapter 6), and the intrinsic uncertainties of the climate problem as discussed above, make assertion No. 5 unlikely to be true.

Its credibility is further diminished by the egregious exaggeration of future CO_2 emission trends in the IPCC's Third Assessment Report. Figure 6 shows the globally-averaged per-person emissions of carbon dioxide in tonnes per capita (tC) since 1960. The average grew steadily from about 0.8 tC to 1.2 tC from 1960 to the early 1970s, and fell thereafter to about 1.15 tC. Since 1970 the average has been just below 1.14.

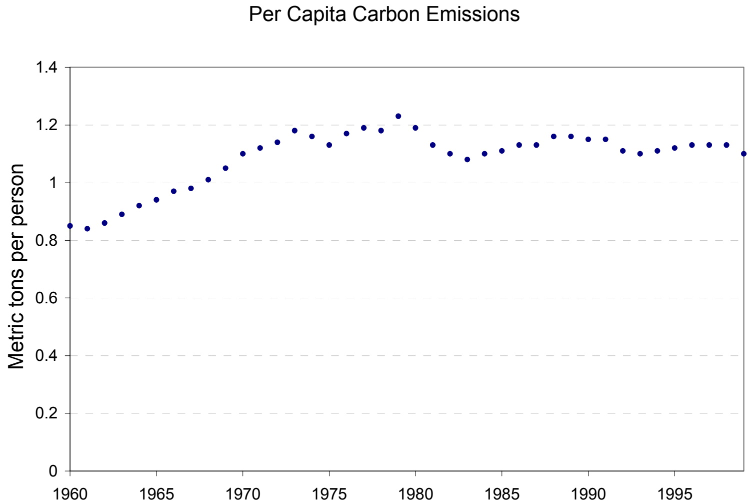

Figure 6: CO_2 emissions in tonnes carbon equivalent (tC) per capita Source: Marland et. al. (2002).

The steadiness of this average during the interval from 1970-1999 is striking in the context of considerable, albeit uneven global per capita income growth during this period. Brazil's per capita income rose 80 percent while Nigeria experienced no real growth at all. In the developed countries there was widespread increase in real per capita income: 60 percent in the US, 74 percent in the UK, 77 percent in Canada, 112 percent in Japan, etc. (Easterly and Sewadeh 2001). Nonetheless carbon dioxide emissions per capita did not rise for the world as a whole.

This lead me to suspect that a long-run equilibrium relationship exists that constrains global CO_2 emissions through the rationing mechanism of global fossil fuel markets. A way to test this would be to examine if per capita emissions are cointegrated across markets. That is, if per capita emissions have unit roots within a country, but across regions or trading blocks they are jointly stationary, then the time series interpretation would be that CO_2 emissions per capita are cointegrated. That, in turn, would imply that the global emissions per person are stationary around a stable mean of just over 1.1 tonnes carbon equivalent (tC) per person. Growth in emissions (per capita) in one region will induce reductions in emissions elsewhere, via the long-run equilibrating mechanism.

I suggested this possibility to Jennifer Orr, a Master's student at Queen's last summer, who did the analysis for her MA research essay. She found evidence (Orr 2003) that per capita CO_2 emissions are indeed I(1) at the country level, but across groups of countries defined by trading intensity cointegrating relationships emerge. More empirical work is needed to fully characterize the phenomena (though because of the short time series, low power will remain a problem). But at this point I think it likely that global per capita CO_2 emissions are pretty invariant to economic growth, at least at a globally-averaged level. We could likely rule out, for instance, the possibility that emissions will exceed 2 tC per capita in the next few decades.

Currently there are about 6.1 billion people in the world. The United Nations projects world population will reach about 9.3 billion persons by 2050 (UN 2002). If CO_2 emissions per capita average 1.14 tC for the next 50 years that would imply total global emissions of 10.6 billion tC by 2050. If emissions per capita range from 1.09 tC to 1.31 by 2050 tC the total emissions range will be 10.2 to 12.2 billion tC.

The IPCC emission scenarios project that by 2020 the average annual emissions per person will be, at a *minimum*, 1.2 tC from fossil fuel consumption. By 2050, the SRES is projecting total emissions of 11 to 23 gigatonnes, implying emissions per capita of between 1.2 and 2.5 tonnes per person (see McKitrick 2003 for more details). This would require a sharp departure from what has been observed historically. If the pattern over the previous decades persists, emissions will fall in the range 10.3 to 12.1 gigatonnes, hovering at the low end of the IPCC scenarios. The standard global warming projections at the low end of the emission scenarios are not the ones people worry about.

6. These changes will be generally deleterious.

If we don't know what changes are likely to happen, and if we have no way of recognizing at a local level if such changes as are happening would not have happened naturally anyway, then this claim is groundless. Climate changes can be good, bad or indifferent. But if anything, warming is better than the alternative.

> "Given the choice, I imagine nobody would opt for a world without any greenhouse, that is, a world with a mean temperature of about 259K [-14 C]. And probably few would opt for an ice-age world with a mean temperature of 275K to 280K [2-7 C]. To this point the greenhouse is seen as good. Further still, a majority clearly continues to see the greenhouse as good up to the present-day mean of about 290K. But, at the next 1.5K a drastic change of opinion sets in: the greenhouse suddenly becomes the sworn enemy of environmental groups, world-wide, to the extent that they rush off to Rio and elsewhere, and make a great deal of noise about it. I find it difficult to understand why. If I am told that computer calculations show immensely deleterious consequences would ensue, then I have a good laugh about it."

Sir Fred Hoyle (1996).

The economic impact depends on the adaptations people undertake. In North America (where the best long term data exist) deaths due to hurricanes and tropical storms are negligible today compared to the period up to the mid-1900's, despite the large increase in population located on the storm-prone southeastern US coastline. The US National Hurricane Centre lists 259 Atlantic cyclones as making landfall in the US over the past 5 centuries (http://www.nhc.noaa.gov/pastdeadlya1.html). The deadliest 39 storms each caused more than 1000 deaths, but they occurred long ago. The deadliest storm after 1981 was hurricane Joan (October 1988) which was 95th most severe with 216 deaths. The deadliest entry since 1995 is Hurricane Opal (October 1995), which is the 182nd most severe, with 59 deaths. Despite the buildup of population in the path of storm tracks, the death rate is dropping. This reflects improved adaptation to climate—a luxury confined to wealthy countries.

Even if we take the worst-case scenario about climate change seriously, the release of CO_2 into the atmosphere represents a trade-off between a climate change and an improvement in economic circumstances. There is good reason to believe the trade-off would be beneficial even if the climate change were costly, but there is also good reason to believe the climate change will not be costly.

Recently Reinsborough (2003) and Adamowicz and Weber (2003) independently conducted Ricardian analyses of Canadian agriculture under conventional climate warming scenarios. Each team used a regression model to relate changes in land values to changes in past local climatological conditions, then used the coefficients to project future land value changes from the regional effects projected by the Canadian Climate Model. Reinsborough found a very small positive effect overall, while Adamowicz and

Weber found a large positive impact, about $500 per acre under the central scenario. The benefits are spread widely over the whole agricultural area of Canada.

These findings mirror those of other teams that project net global gains in agriculture (Mendelsohn *et. al.* 1999, 2000) and forestry (Sohngen and Mendelsohn 1998). Beyond these sectors most economic activity (manufacturing, services, etc) takes place indoors and is not affected by the weather.

As for climate extremes and severe weather, a recent review prepared for the Alberta government by a retired Environment Canada meteorologist (Khandekar 2002) concluded that there is no evidence of an increasing trend in extreme weather events anywhere in Canada. Other studies have likewise concluded that there is no upward trend in the frequency of storms, nor is there any upward trend in the severity of storms (Landsea *et. al.* 1996, Zhang *et. al.* 2000). If so much global warming has happened in the 20th century, it follows that it does not induce more storm activity.

7. We ought to reduce emissions of CO_2.

Now we get to the normative issue, and here the conventional tools of economic reasoning are very pertinent. The standard graphical tool of environmental economics shows the marginal damages of emissions and the marginal abatement cost associated with reducing emissions. This latter curve is equivalent to the marginal benefits of the activity generating the emissions.

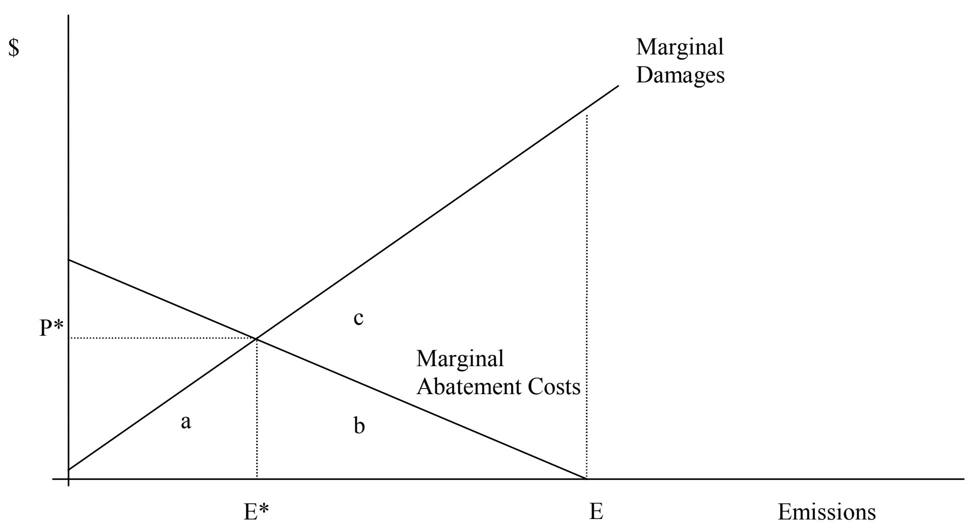

Figure 7: The Optimal Emissions Level.

If emissions are initially at point E, the total social damages equals the area under the marginal damages curve, which is a+b+c. If emissions are reduced from E to E*, the costs of doing so is represented by the area under the Marginal Abatement Cost function between E and E*, which is b. The gain to society is the reduction in damages, equal to the area b+c. Consequently, the net gain of reducing emissions is area c. If emissions were reduced further, the marginal cost of doing so (shown along the MAC curve) would exceed the marginal reduction in damages (shown along the MD curve), so such a move would be welfare-reducing. And if emissions were not reduced as far as E*, the foregone benefits of emission reduction would exceed the cost savings. Consequently, at the optimal emissions level E*, the net social gain (=c) of pollution reduction is maximized.

The above story applies when we are beginning from a position of zero regulation, which is not quite true for CO_2 since there are regulations on fuel use and fuel efficiency and so forth, but it's a close enough approximation. If we start at the unregulated emissions level *and the optimum is an interior point* then we ought to reduce emissions. If instead the diagram looks like Figure 8, there is no reason to reduce emissions below the unregulated level, even if there is some level at which emissions are acknowledged to be damaging.

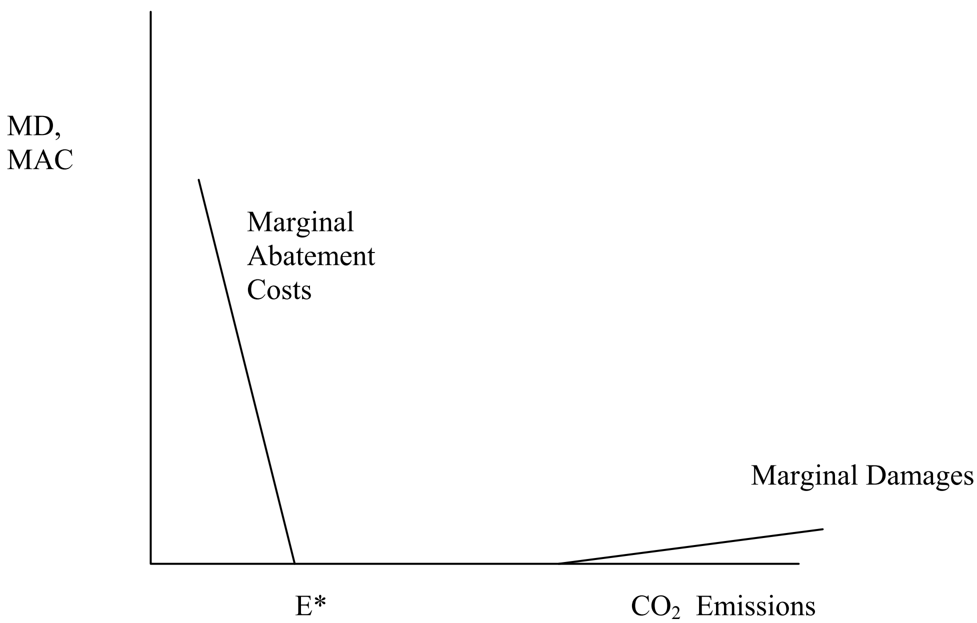

Figure 8. The Marginal Damages and Marginal Abatement Costs for Global CO_2 Emissions

This, I submit, is the situation the world is in. It is certainly the situation for Canada individually. Reducing emissions generates costs which go up with the triangular area under the MAC, but generate no offsetting benefits since the area under the MD curve does not change. Invoking benefits due to "energy efficiency" is no help since the MAC is drawn on the assumption that these are fully already realized. If they are not, the public policy issue is energy efficiency, not emission reductions. But energy efficiency is like labour productivity: governments always want it to increase, but it is easy to spend a lot of money without getting the desired result. Energy efficiency does improve over time but if there was a magic formula for accelerating the process I think we'd know it by now.

At this point it is also important to remind ourselves that CO_2 is not a pollutant. Noxious air contaminants like SO_2, NO_x, ozone, smoke particles, etc. cause direct damages to health and utility. CO_2 is harmless, odourless, colourless and is a naturally occurring part of our atmosphere and respiration. No one would be concerned about regulating it except for its possible role in the climate. But emissions themselves do not cause damage, only (in principle) the atmospheric concentration does, and this changes very slowly in response to large variations in emissions. That's why the MD line is so flat in Figure 8: any potential damages due to CO_2 emissions are constant over large ranges of feasible emission levels, since the gas is well-mixed on a global level.

8. The best mechanism to accomplish this is through the Kyoto Protocol.

A further point to be gleaned from Figures 7 and 8 is that, if the volume of abatement is denoted *A* (the difference between observed emissions and E*) then the total abatement costs go up with the square of *A*, while the total benefits rise at a declining rate. This matters because some proponents of Kyoto argue that while Kyoto will do nothing for the world atmosphere it is just the first of what will be many more ambitious agreements. It is tempting to invoke the *benefits* of those agreements, but the *costs* must also be invoked. And if Kyoto fails the benefit-cost test the subsequent agreements will as well, since the net benefits decline.

Treaty participants are divided into Annex B and non-Annex B countries. The distinction refers to whether the country has accepted an emissions reduction target. Non-Annex B countries, such as India, China and other developing countries, can join and ratify the treaty, though they are not required to cut emissions.

Annex B countries include the industrialized west and some former Soviet Bloc members. The treaty will enter into force if it is ratified by 55 countries, including enough Annex B members to account for 55 percent of the Annex B emissions. As of October 2003, 119 countries had ratified the Protocol, including 32 Annex B members accounting for 44.2 percent of Annex B emissions. The US accounts for 36.1 percent and the Russian Federation accounts for 17.4 percent of Annex B emissions. Neither of these countries has ratified. The US has indicated that it has no intention of doing so, while Russia is still considering the matter. Australia, which has 2.1 percent of Annex B emissions, has also indicated it will not ratify.

The European Union ratified jointly,as is permitted under Article 4, but must secure internal agreement on the sharing of the emission reduction requirements among themselves. Japan ratified the treaty, though the government proposed only voluntary measures and plans to revisit the issue in several years. Japan's ratification does not seem to involve imminent formal implementation plans.

Canada's Annex B share is only 3.3 percent, so our decision on its own is not particularly influential in the larger scheme of events. However, if the Russian Federation ratifies, the treaty enters into force. Likewise if they do not, the treaty dies. That is why there has been such intense interest in Russia's views lately: and the hints at this point are that the Russians are unlikely to ratify. If they do ratify, because of the economic collapse in the early 1990s Russia's emissions are below their target level. This gives them credits that they can sell to other countries. The large block of Russian credits is often referred to as "hot air."

For the purpose of the policy discussions, emissions are measured in "Megatonnes (metric tons) carbon dioxide equivalent", or MT. Canada's emissions as of 2010 are projected to be 809 MT, while the Kyoto target is 571 MT. This creates a gap of about 240 MT, about 30 percent. One reason this is so much more daunting than controlling SO_2 or particulates is that CO_2 cannot be "scrubbed." If you burn fuel you release it, regardless of how efficiently you burn and filter the smoke. The only large-scale way to reduce emissions is to reduce fuel consumption.

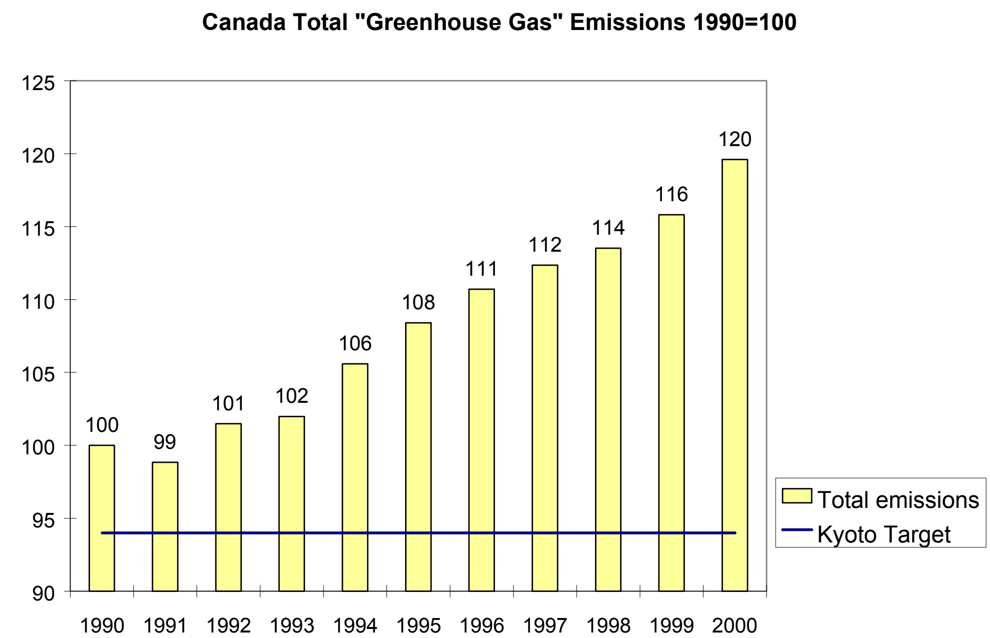

Figure 9: Canada's Greenhouse Gas Emissions and the Kyoto Target.
Source: Environment Canada State of the Environment Infobase
http://www.ec.gc.ca/soer-ree/English/indicator_series/techs.cfm?tech_id=15&issue_id=4&supp=1#data

The treaty requires compliance, on average, over the period 2008 to 2012 and treaty members must submit evidence of having made "substantial progress" towards meeting their goals by 2005. The treaty does not specify what happens after 2012, though plans are being made for a subsequent treaty that would tighten the targets further. There are no financial penalties for non-attainment of one's target, however a proposed rule would require deeper cuts in subsequent periods by parties failing to meet their goals in the current compliance period.

Following the signing of the original treaty, negotiations at Bonn and Marrakech in 2001 authorized the use of "sinks" credits. Under this arrangement, Canada, Japan, Russia and other countries are allowed to claim credits for the fact that forest and plant growth within their boundaries draws CO_2 from the air. In Canada's case the original target was relaxed by 10 percent (we can claim 24 MT worth of sinks from existing plant and forest growth).

Since then, Canada unsuccessfully sought 70 MT worth of credits for so-called 'clean energy exports.' Under this proposal, if another country, for example, Japan, reduces its emissions by switching from coal to natural gas from Canada (which emits less CO_2 per joule), Ottawa wants to claim the reduction in the other country's emissions as reductions for Canada. The accounting rules for Kyoto do not allow this except by prior agreement under something called the Joint Implementation plan. The idea is incoherent anyway. Canada would not have accepted the obvious corollary, which is that if a country buys coal from Canada but *could have* bought natural gas, we should be penalized for the extra emissions.

The original form of Kyoto required countries responsible for about half the world's CO_2 emissions to reduce them to just under five percent below 1990 levels. Because of economic growth, by 2010 emissions among participating countries could be at least 30 percent above their aggregate target.

Consequently the original Kyoto would have led to a nominal target amounting to a 15 percent cut in global emissions as of that date (half of 30 percent).

However, there is the leakage effect to consider. Reduction in fossil fuel consumption in Kyoto participants (Annex B countries) would lower the world price of fuels and induce higher consumption in non-Annex B countries. That development, as well as migration of energy-intensive capital, would cause emissions to increase in non-Annex B countries, partly offsetting the original emission reductions. The process is known as the "leakage effect." Global economic simulations have found the leakage rate to be anywhere from below 10 to almost 50 percent (see, e.g., Oliviera-Martins *et. al*, 1992, Smith 1994). If the leakage rate is 30 percent, then the emission cuts in Annex B countries will induce emission increases elsewhere that offset 30 percent of the cuts. Under the original terms of Kyoto a 30-percent leakage rate would imply total global emissions would fall by about 11 percent (15 times 70 percent).

The US withdrawal from Kyoto reduced the impact of the treaty further, because the United States is responsible for over one-third of Annex B emissions. While the United States proposed some unilateral initiatives, the country's withdrawal means about two-thirds of the world's emissions are not covered by Kyoto. If the remaining participants reduce their emissions by 30 percent, this amounts to a 10 percent cut in global emissions (one-third of 30 percent) as of 2010. But if the leakage rate is 30 percent, global emissions will only be reduced by about seven percent against 2010 levels. Once we add in the credits for land "sinks" given to the remaining participants we get an expected global emissions reduction of about six percent of 2010 emissions.

Kyoto's climate impact was analyzed in a simulation model by Wigley (1998). The original form of the treaty, under the assumption that additional accords are developed subsequently to keep emissions from going back up to business-as-usual levels after 2012, only slowed the accumulation of CO_2 in the atmosphere by a small amount. The concentration of CO_2 reached at 2100 under business-as-usual would be reached about five years later under Kyoto-plus-subsequent treaties. With 60 percent of the original emission reductions undone, this small delay shrinks as well. Consequently Kyoto can, at best, only delay by a few years whatever would happen as a result of increasing CO_2 in the atmosphere, unless the Protocol's targets are later tightened.

Consequently, at the global level, the Kyoto treaty is already a dead letter. This was confirmed in a recent article in the CJE by Bohringer and Vogt (2003), who compiled the exemptions and loopholes and showed that upon implementation, Russia's hot air would more than cover the existing demand for emission credits, making the overall emission reduction as a result of implementing Kyoto roughly zero.

As for the costs, Randy Wigle and I surveyed them in a C.D. Howe Commentary last year (McKitrick and Wigle 2002). The difficulty of coming up with cost estimates is that there is no coherent implementation plan. It is disingenuous for the federal cabinet to cite cost estimates that apply to efficient pricing mechanisms (like CO_2 taxes) and present them as if they apply to any and all schemes for compliance. There is a narrow range of policy types that can achieve cost-effectiveness, as I'll discuss shortly.

I thought I had a pessimistic view of Canada's ability to comply with Kyoto, but then I participated in a panel at Queen's with Chris Green of McGill. Professor Green does not dispute the IPCC view of the science as I do, but he goes further than me in warning about the costs. I have published estimates that it will shave about 2.5 percent off our national income: Chris thinks 8-10 percent is more realistic (Green 2003).

His analysis is beguilingly simple. There is a simple identity to describe total emissions of CO_2:

$$E \equiv \frac{E}{Y} \times \frac{Y}{P} \times P$$

where E denotes emissions, Y denotes GDP, and P denotes population. Denote emissions intensity of output as e and income per capita as y. Then taking logs and time derivatives we have

$$\%\Delta E \equiv \%\Delta e + \%\Delta y + \%\Delta P$$

where the $\%\Delta$ denotes annual percent change. This expression is called the Kaya identity. Greenhouse emissions are now about 25 percent above the Kyoto target. To get them down to the target between now and 2010, which is required to achieve Kyoto, emissions will have to decline by just over 3 percent annually. Population grows by about one percent per year. Emissions intensity in Canada fell by about 2 percent per year during the oil price shocks of the 1970s, but since 1990 the decline has been only about 0.6 percent per year. Since we require

$$\%\Delta e + \%\Delta y + \%\Delta P = -3$$

and current data suggest

$$\%\Delta e + \%\Delta P = 1 - 0.6 = +0.4 \text{ ,}$$

we need to ensure

$$\%\Delta y = -3.4$$

for the rest of the decade. In other words we need Canadians to accept a reduction in real per capita income of about 3.4% per year from now until 2010. After that per capita income cannot grow by more than $\%\Delta e - \%\Delta P$ annually, which by historical standards is about -0.4%. Not a happy prospect.

9. **The best way for Canada to comply with Kyoto is to pursue a package of measures as outlined in the Canadian Climate Change Plan (CCCP), which includes encouraging Canadians to do their laundry in cold water.**

Figure 9. CCCP

When talking about the "best" way to implement a policy target we should focus on cost-effectiveness. In economics this means minimizing the cost of getting the job done. In policy settings the term seems to mean "less than infinite cost" but we can try for a bit more rigour than that.

The key to cost-efficient pollution policy is that marginal abatement costs across all polluters must be equal. This is called the 'equimarginal' principle. To prove it, first note that we are assuming emissions mix uniformly in the environment, so all polluters face a common marginal damages curve. Each polluter i gets (decreasing marginal) benefits from generating emissions e_i so its profits can be written as a function of emissions, $\pi^i(e_i)$, and its marginal benefits of emissions, a.k.a. its marginal abatement cost curve, can be written $\frac{\partial \pi^i}{\partial e_i}$.

The regulator wants to achieve some overall emissions level $E = \sum_i e_i$. The policy challenge is to do this in such a way as to minimize the economic costs, or equivalently, to maximize the economic benefits from the allowed total emission levels E:

$$\max w.r.t. \{e_i\} \sum_i \pi^i(e_i) \text{ subject to } \sum_i e_i = E .$$

The Lagrangian function for this constrained optimization problem is:

$$L = \sum_i \pi^i(e_i) - \lambda \left[\sum_i e_i - E \right].$$

The first order conditions, with respect to the e_i's are each written

$$\frac{\partial L}{\partial e_i} = \frac{\partial \pi^i(e_i)}{\partial e_i} - \lambda = 0$$

and since the λ's are constant this implies that

$$\frac{\partial \pi^i(e_i)}{\partial e_i} = \frac{\partial \pi^j(e_j)}{\partial e_j}$$

for any pair of polluters *i,j*; or in other words, the MAC's across all pollution sources should be equal.

To see the intuition of this result, suppose that as a result of a pollution control policy, two firms must reduce their emissions a certain amount each. The last unit of emissions reduction cost firm A $1200, and the last unit of emission reduction cost firm B $200. If A had paid firm B, say, $300, to cut its emissions by one more unit, and A had cut its emissions one less unit, A would save (1200-300)=900, while B would earn 300 for an action that cost it 200, for a net gain of 100. Consequently, while the overall emissions would have been identical, both firms would have been better off. As long as MAC's differ at the margin, the possibility for a mutually-advantageous rearrangement of abatement activity exists. That is why equimarginality is a necessary condition for cost-efficiency. Moreover, cost-efficiency is a necessary condition for optimality, since if the MAC's differ at the margin, they cannot all have abated to the point where marginal damages equal marginal abatement costs, which defines the optimal level of emissions for each source.

Policies to achieve equimarginal costs must be price-based. To equate marginal costs across decentralized consumers they must supply a price signal, either through a market for permits or a tax on emissions. The optimal tax, as shown in Figure 8, is zero. So we have, at present, the optimal economic instrument for CO_2 emissions already in place. A variant on the optimal policy would be to freely distribute emission permits until the trading price is zero.

Unfortunately the CCCP goes in a different direction. Following consultations over the summer of 2002 a plan was released in November 2002 (OK, it's actually called the "Climate Change Plan for Canada" or CCPC). It assumes that pre-existing programs will achieve 80 MT emission reductions. New measures were proposed that will achieve about 100 MT cuts, and a future phase will identify another 60 MT reductions.

The actions described by this Plan were those that came out of the earlier "Issues Tables" process. The language describing them is extremely vague, lacking clear timetables, mechanisms and cost measures. For instance, one plan is to retrofit a fifth of the national building stock. It is explained in the Plan as follows:

Energy efficiency retrofit of 20 percent of housing by 2010 (1.5 MT)

This Plan proposes the goal of energy efficiency retrofits for 20 percent of housing by 2010. Cost shared audits and information for homeowners under the Energuide for Houses initiative will be expanded. Financial incentives for retrofits will also be explored.

Energy efficiency retrofit of 20 percent of buildings by 2010 (1.2 MT)

This Plan proposes the goal of retrofitting 20 percent of the commercial and institutional buildings stock to higher energy efficiency levels by 2010. This could be achieved through collaboration between provincial/territorial governments, municipalities, Aboriginal people, non-governmental organizations, trade associations and the private sector. Commercial and institutional building owners would be consulted on how to encourage retrofits. They can contribute, for example, through the formation of buyers groups to reduce price and risk in the acquisition of new technologies and products.

(http://www.climatechange.gc.ca/plan_for_canada/plan/chap_3_2.html)

Note that these ambitious undertakings would yield only 2.7 MT emissions cuts, or about 1% of the estimated Kyoto target.

Households are challenged to reduce emissions by one tonne per person, through measures such as:

On the Road
Transportation accounts for half of individual greenhouse gas emissions. The kind of vehicle and the number of kilometres driven can have a huge impact on greenhouse gas emissions. Canadians can take many actions to reduce emissions from transportation.

* Buy a fuel-efficient vehicle – A 25 percent more fuel-efficient vehicle could reduce emissions by more than one tonne per year and save $360 on an average annual gasoline bill of $1440.
* Use ethanol blend gasoline – Current vehicles can use up to 10 percent ethanol blended gasoline without any adjustment to or effect on the engine.
* Use the car less – Driving 10 percent less, by walking, cycling, carpooling, or taking public transit, can reduce greenhouse gas emissions by 0.2 to 0.8 tonnes per year, depending on the vehicle.
* Reduce idling – If every Canadian motorist avoided idling their vehicles for just five minutes a day, all year, more than 1.6 million tonnes of carbon dioxide, along with other toxic substances, would not enter the air.

(http://www.climatechange.gc.ca/plan_for_canada/plan/chap_4.html#a)

The Plan, so-called, is long on expenditure, short on tangible detail, and anything remotely resembling the concept of cost-efficiency is missing, even though the term is used throughout. The question to be asked of a program like subsidies for retrofitting houses is: how much would this cost per tonne of emission reductions? The long, discouraging experience with programs like the old CHIP grants ought to have taught governments that “energy efficiency” subsidies deliver little measurable value, for all their costs. Subsidies mainly end up paying people to do something they were going to do anyway, and where the subsidy might induce, say, adding extra insulation in the Jones’ attic, it is very expensive to go back and audit if the developer or homeowner actually did the work they promised to do when they took the money.

The implementation of Kyoto is also submerged in the usual political soup. The auto industry, of such political importance in Ontario, was quietly exempted in November of last year. The oil and gas sector has been promised it won't have to spend more than $15 per tonne of abatement, even though at that price (according to the simulations done for the federal government by Informetrica last year) for the nation as a whole only about 25 MT of emission reductions altogether would occur, and the price effect on oil will only be a few cents per barrel: not enough to change anyone's behaviour. The Ontario power sector has been operating under a rate freeze (NB: it seems to have been scrapped today—October 31, 2003—and will be replaced with a pricing board) that undermines any plans to reduce electricity consumption. And Alberta has introduced Bill 37, which forbids the Alberta government from entering into any federal-provincial emissions control deal that is inconsistent with the Alberta government's plan.

In all, the Canadian plan for implementing Kyoto is in ruins, and it is inconceivable that we will meet the target. It is looking unlikely we will even hit the business-as-usual target of 810 MT at the current rate of emissions growth. Following through with the CCPC, such as by washing clothes in cold water, will have no bearing on whether Canada achieves the Kyoto target. To the extent that doing a cold-water wash is a private cost, it is a cost with no offsetting benefit. If hot water is better for your laundry, use hot water.

11. Conclusions

My conclusions can be briefly stated as the opposites of the assertions made in the introduction.

1. The "climate" is not subject to precise definition, and its mean state cannot be measured with precision.

2. The equations of motion of the climate are unknown. The full range of natural variability is not well-known and future climate states cannot be predicted.

3. By adding to the stock of atmospheric CO_2 humans have an affect on the climate which may involve a general warming, cooling or some combination of both, at the Earth's surface, but it is unpredictable.

4. The present state of the climate reflects primarily natural causes, and if infrared-absorption plays a role it seems very minor.

5. Continued use of fossil fuels following any reasonable trajectory, by adding CO_2 to the air, may at most cause small and barely noticeable changes to the future climate.

6. These changes will be impossible to detect in any location, but on balance they will probably be beneficial.

7. The optimal emissions of CO_2 corresponds with the unconstrained level.

8. The Kyoto Protocol is a costly initiative that yields no environmental benefit.

9. There is no reason for Canada to comply with Kyoto, so Canadians should be left alone to do their laundry in whatever water they find works best.

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