The likelihood of climate change: A methodology to assess the risk and the appropriate defence.

Harvey Stern
Special Services Unit
Bureau of Meteorology
Box 1289K, Melbourne, 3001
Australia.

1. Introduction.

"The analogy between meteorology and astronomy is often made...There is a closer resemblance, to my mind, between meteorology and economics. Both deal fundamentally with the problem of energy transformations and distribution - in economics, the transformation of labour into goods and their subsequent exchange and distribution; in meteorology, transformation and distribution of the energy received from the sun. Both systems are subject to extremely capricious external influences..." (Sutton, 1951).

"Economists are sometimes challenged to cite a discovery from economics that is both true and surprising. For many years, the principle of comparative advantage was the best example. An equally good reply, thanks to Messrs Black and Scholes (Black and Scholes, 1973) is the theory of option pricing" (The Economist, 1991).

The beautiful connection between these two quotes will become apparent during the course of the present paper as one realises that

. the basis for costing (economics) of climate change (meteorology) is options pricing theory (economics); and,

. that theory originates, in part, from heat transfer theory (meteorology) - see Kreith and Bohm (1986).

The Australian government recently established an Industry Commission (Industry Commission, 1991) to study the costs and benefits of reducing greenhouse gas emissions.

The Industry Commission concluded that "current knowledge does not definitively establish that an enhanced greenhouse effect with adverse implications exists ...(and that)...there are many major uncertainties, and it will be another decade before it is possible to say whether or not observed recent climate change has been driven by anthropogenic influences".

And, the costs of premature action may be great. In the News Release which accompanied the release of its report, the Industry Commission warns that, for Australia, "...achieving a 20 per cent reduction in emissions from 1988 levels (the Toronto target) would reduce national output by 1.5 per cent".

The issue of global climate change has aroused considerable debate in the scientific community. Views on trends in global climate have ranged over the years from those who forecast a substantial (economically significant) temperature rise, to those who see the present apparent upwards trend in mean temperature as a part of the natural fluctuations, and finally, to those who have predicted a substantial trend to lower temperatures.

The physical bases for these predictions are as varied as the explanations advanced for previous climate shifts. These explanations cite, among other causes, changes in the earth's axis of rotation and its orbit around the sun, aerosols emitted by increased volcanic activity, carbon dioxide and other greenhouse gas emissions, as being responsible for climate variations. More recently, global climate shifts have been attributed to variations in the output of the sun's energy, some correlation of the mean temperature to the period length of the sunspot cycle being noted.

That no numerical global climate model (GCM) referred to in the literature has ever been reported as correctly replicating the "warming-slight cooling-warming" scenario observed this century, underlines how fragile is our understanding of the complexity of the processes involved.

These issues make necessary the development of an appropriate risk-return model which would enable the calculation of the appropriate strategy to adopt both from a micro-economic and macro-economic standpoint.

2. Methodology.

Firstly, regard the global mean temperature

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(GMT) in the same manner as one would a financial commodity futures contract and value it accordingly (Black, 1976; Gastineau, 1988). The theoretical value of such a futures contract is a function of 'holding costs minus income generated by the underlying financial instrument'. To illustrate, the value of a share price index (SPI) futures contract is a function of 'interest rate minus dividend return from the underlying shares'.

The above process yields theoretical valuations (on this basis the theoretical value of a GMT futures contract will equal the current GMT).

The operation of financial markets then leads to departures from the theoretical value of futures contracts, which are a function of anticipated movements in the value of the underlying.

Secondly, assume that GMT futures contracts are available to be bought and sold and that associated put and call option contracts (Gastineau, 1988) are available to be written or taken, and so alter the risk-return characteristics associated with the GMT contract.

The strategy, therefore, is to establish the economic consequences of movements in the GMT, these economic consequences being applied across the complete range of scales; i.e. from the global economy down to the smallest company (e.g. a ski equipment manufacturer).

These economic consequences can be replicated in a combination of GMT futures contracts and an associated set of 'written' and 'taken' put and call option contracts at various strikes and expiry dates.

The use of the methodology presented derives from an assumption that the two time series (SPI and GMT) follow a "random walk" principle (Cheng and Deets, 1971 and Gordon, 1991), that is, the value of the next element in a series is independent of preceding values.

Alternatively, it may be argued that the market would evaluate the cost of insurance against global warming by taking into account the spread of predictions from GCMs. However, the running of GCMs is quite analogous to the efforts which are undertaken to forecast the movement of the SPI. Rarely do the contracts significantly vary in value from the theoretical.

3. Illustrative examples

Two examples, illustrating the methodology, are now presented.

Example 1:
Protecting against the risk of diminishing industrial output associated with global warming.

Assumptions -

(1) That long term GMT is 288K (approximately 15°C) and that the departures given by the Carbon Dioxide Information Analysis Center (CDIAC, 1990), are regarded as being from that figure (e.g. -0.21 represents 287.79K).
(2) That the insurance is calculated for protection against a diminishing in the globe's increase in its industrial output that would have occurred except for adverse effects of global warming.
(3) That industrial output is unaffected by global warming as the GMT rises, until the temperature reaches a departure from the long term of +1.34°C (or 1.00°C above the 1988 CDIAC value). A temperature increase from this point is assumed to adversely affect industrial output, causing it to decline in a linear manner as GMT rises further to +2.34°C, at which point the annual rate of increase in industrial output is reduced to zero. Continued rise in GMT from this point is assumed to lead to an adverse effect increasing at the same rate. So, by the time the GMT departure is at +3.34°C, the rate of decline in global industrial output is equivalent to the current rate of increase. Note that these scenarios of GMT change are consistent with GCM output (Bureau of Meteorology, 1992).
(4) Protection is required for a period of 100 years.

Calculation -

This is equivalent to calculating the cost of an American call option contract on the value of the Futures GMT contract with the following characteristics:

. Spot = 288.34K.
. Strike = 289.34K.
. Volatility = 0.0069% (based on the CDIAC

GMT data series)
. Interest rate = 0% (assuming that the only money which changes hands is that associated with variation margins).

Utilising the Black and Scholes (1973) call option formula, as modified for future style options (Gastineau, 1988), the calculation yields 0.15 - see also Black (1976).

So, for protection under the aforementioned assumptions, the full cost of protection is $15 for every $100 of industrial growth to be achieved over the next 100 years.

But if, for example, the effect of reducing industrial output by 1.5% (referred to earlier) is compounded annually, after 100 years (and if one assumes a 3% annual growth rate otherwise) we are

. looking at a level of annual industrial output 77% below that which otherwise would have been produced after 100 years; and,
. furthermore, the total industrial output sacrificed under these assumptions would be 47% of that otherwise achieved over the full period.

The important issue is not so much the validity (or otherwise) of the many assumptions that are made, but that they form the basis for opening up a quantitative approach to determine cost and appropriate action.

And, there is one further assumption that is implied by the methodology. This is the assumption that taking actions to reduce greenhouse gas emissions will, indeed, arrest the global warming, if it is, in fact, occurring at all.

Example 2:
Protecting against the risk of decreasing value of a company likely to be adversely affected by global warming (e.g. a manufacturer of ski equipment).

Assumptions -

(1) That long term GMT is 288K (approximately 15°C) and departures are regarded as being from that figure (e.g. -0.21 represents 287.79K)
(2) That the insurance is calculated for protection against a decrease in the value of a company, which occurs as GMT rises.
(3) That the value is unaffected by global warming as the GMT rises, until the temperature reaches a departure from the long term of 1.34°C. (1.00°C above the CDIAC 1988 value). A temperature increase from this point is assumed to adversely affect value, causing it to decline in a linear manner as GMT rises further to +2.34°C, at which point the value is reduced to zero. Continued rise in GMT from this point has no further effect upon the company's value as it cannot decline in value below zero.
(4) Protection is required for a period of 100 years.

Calculation -

This is equivalent to calculating the difference between the cost of two American call option contracts on the value of the Futures GMT contract with the following characteristics:

First contract -

. Spot = 288.34K.
. Strike = 289.34K.
. Volatility = 0.0069% (based on the CDIAC GMT data series)
. Interest rate = 0%

Utilising Black and Scholes call option formula, as modified by Black for futures contracts, the calculation yields 0.15.

Second contract -

. Spot = 288.34A.
. Strike = 290.34A.
. Volatility = 0.0069% (based on GMT data series)
. Interest rate = 0%

Utilising the Black and Scholes (1973) call option formula, as modified for future style options (Gastineau, 1988), the calculation yields 0.03 - see also Black, 1976.

So, the cost of insurance is the cost of the first contract minus the cost of the second contract, namely 0.12, or 12% of the future value of the company. Note again that no money changes hands initially, and it is possible that only at the end of the options' life will settlement occur.

4. Summary and conclusions.

A methodology for calculating the appropriate cost of defending against the possible onset of global warming has been presented.

The calculation procedure is based on the premise that current knowledge does not definitively establish that an enhanced greenhouse effect with adverse implications exists.

Under this premise and utilising the results of other work on the time series which records the global mean temperature record, the assumption of "random walk" with regard to global mean temperature is regarded as valid.

One then borrows from financial markets, the behaviour of which are also regarded as "random walk", to value hedging and speculative instruments that might equally apply to climate fluctuations.

In valuing the climate fluctuation hedging and speculative instruments, wide-ranging assumptions are made. But, the methodology does provide a tool whereby the cost of the risk faced can be determined (whether it is in the case of determining that risk on a global scale, or on a company specific scale).

Use of these financial instruments would lead to those concerned being compensated provided they were on the correct side of the contract. Conversely, those on the wrong side of the contract would have to provide that compensation.

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