

**INSURANCE AND CLIMATE CHANGE: INSURING RISK AND
CHANGES IN RISK**

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Paper prepared for
“The Irrational Economist” Conference
and Book Writing in honor of Howard Kunreuther

December 4-5, 2008

Chapter to appear in
The Irrational Economist: Future Directions in Behavioral Economics and Risk Management
E. Michel-Kerjan and P. Slovic (eds.) *Public Affairs Press*. (forthcoming 2009)

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November 20, 2008

INTRODUCTION

Insurance is the transfer of one person's risk to another who can absorb that risk at lower costs. Risk is not simply a precondition for insurance; rather insurance is meaningless without risk. Uncertainty is another matter. If we cannot specify the level of risk, then insurance companies get nervous. Without clearly defined risk, it becomes difficult to set premiums, determine how much capital to hold and insurance ratings might be compromised. Uncertainty, it seems, deters the functioning of insurance.¹

When we contemplate climate change, the defining feature seems to be uncertainty. There is an emerging scientific consensus that anthropomorphic factors are significantly changing the atmosphere. However, projections of climatic impact vary. Most scientists seem to agree that temperatures and sea levels will rise if we continue to pump out greenhouse gases, GHG's, (or even if we stabilize current production), but the extent and timing of such anticipated changes is surrounded by a large margin of error. When it comes to extrapolating from broad indicators of climate change (mean global temperature and sea level) to changes in natural hazard risk (storms, droughts, etc), the belt of uncertainty expands. And if we drill down from the impact of climate change on global hazard to the impact on regional hazard risk, then our knowledge of future risk levels is scant indeed. Thus, we could perhaps summarize the potential impact of climate change on the hazards we typically insure by the phrases "increasing risk" and "enormous uncertainty". We simply do not know with any precision how the risk that we seek to insure will change over time.

How will insurance function under such conditions? One response might be that, if climate change follows a slow evolution, the problem will take care of itself. Insurance contracts typically are for short periods, typically one year, and each year insurers and policyholders will update with the latest information and write new contracts. True, risk levels may change a little, but premiums will be fine tuned, and the impact will be gradual.

But what if climate change is more rapid and sudden? In this case, actuaries cannot rely on a long data record to estimate loss distributions. Old data degrades thus compromising the sample size. This implies that statistical updating on the basis of very recent loss experience can be quite dramatic. Rate increases following single

¹ Howard Kunreuther, Jacqueline Meszaros and Robin Hogart and Mark Spranca, 1995, "Ambiguity and Underwriter Decision Processes", *Journal of Economic Behavior and Organization*, 26: 337-352. Also Neil Doherty and Paul Kleindorfer, **Error! Main Document Only.Error! Main Document Only.** Ambiguity and the Insurance of Catastrophe Losses, Working Paper, Risk and Decision Processes Center, Wharton School.

events such as hurricane Andrew or the cluster of storms of 2005 (including Katrina) were large.² In an unstable climate, much of the risk that people face is the *risk that risk itself may change*. Thus, even if insured over the long haul, people face the risk that future premiums may change dramatically. Accompanying these changes in the level of risk, will be changes in the market values of assets that are exposed to risk. We may expect climate change to affect home prices according to changes in local hazard.

Thus, an unstable climate, not only generates uncertainty about future risks, it generates new risk. These new risks include risky premiums and risky asset prices. What are the challenges to insurance markets introduced by climate change? Will the normal conditions for insurability be present? Do insurance contracts need to be redesigned? Can insurance cover the new risks of volatile premiums and risky house prices? To address these questions, it is helpful to examine the nature of the risk that faces people in an unstable climate. I will argue that climate changes can be represented as a compound lottery with risk present in both the first and second stages. The *stage 1* risks are the premium instability and asset price volatility, whereas the *stage 2* risks are those we normally associate with insurance. However, the first and second stages exhibit very different characteristics which carry different implications for insurance. I will then use this characterization to address a proposal floated by Howard and his colleagues; long term insurance for hazard risk.

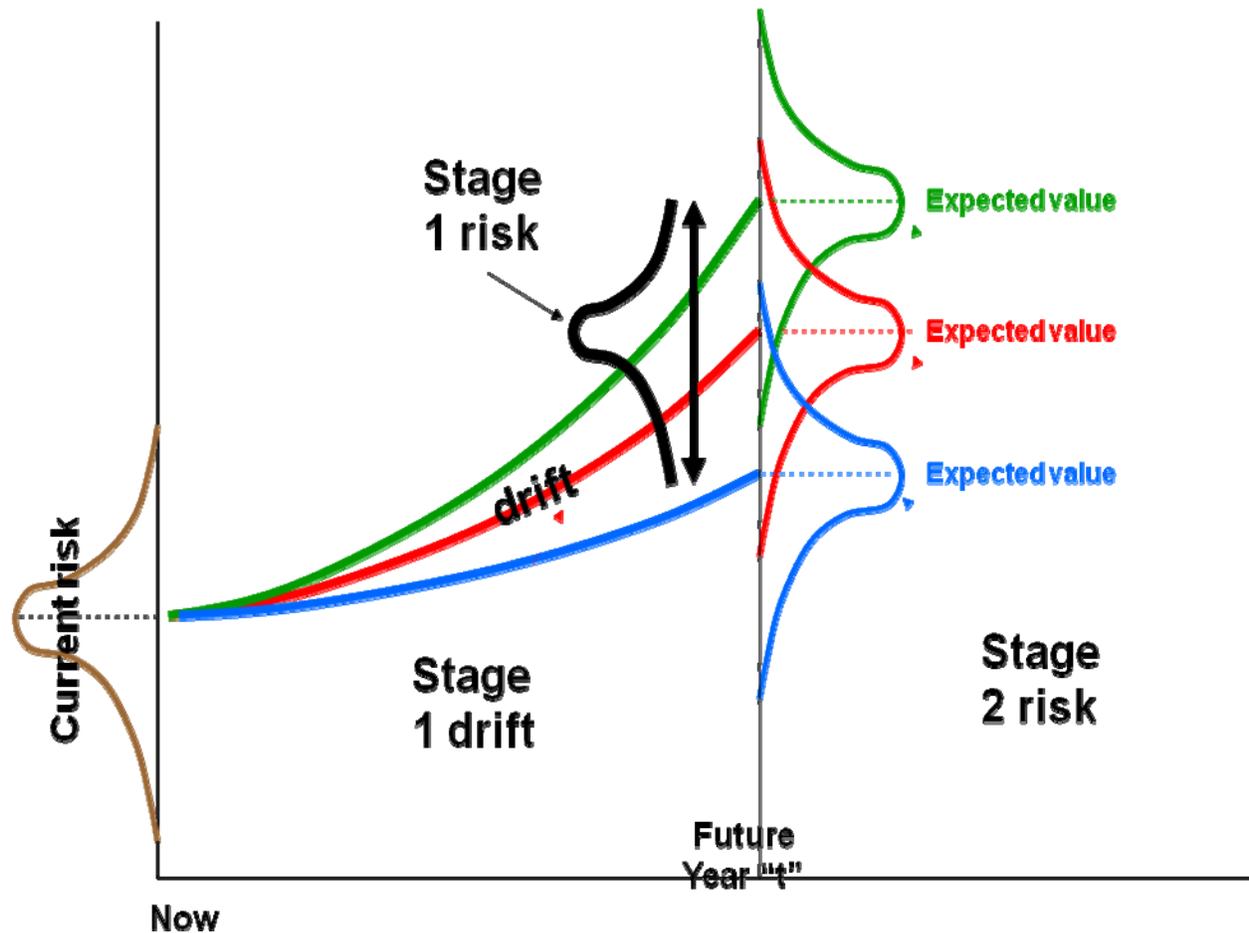
CLIMATE CHANGE AS A COMPOUND LOTTERY

The evolution of risk under conditions of climate change can be viewed as a multi-stage lottery as shown in Figure 1. Currently, the risk for a particular insurance portfolio (the expected values of the component exposures together with variances, covariances, VaR, etc.), can be depicted by a distribution which is, to some degree, known. How will this risk change over time? From the present we can contemplate the risk in some future year t . We cannot specify now what the risk might be in that year. Indeed there are many distributions that could occur each with their own expected value and higher moments.³ Between the present and time t , the climate risk will drift, though we cannot be sure about which path it will take. I have shown three possible paths, each depict potential evolution of the expected value of the time t distribution. As time t approaches, uncertainty will be resolved, but only to some extent. We will not have the luxury of a long and stable historical record with which to estimate the year t distribution and we will rely on other methods (e.g., meteorological models) to estimate the

² To be fair, rate increase would reflect both the change in estimated expected loss and the higher cost of capital that results from post-loss capital rationing.

³ I have shown the variances as seemingly the same in the figure. Of course, we would also be unsure about all moments.

distribution.



Stage 2 risk. In this structure, we can see different types of risk. At time t , we will have conventional contemporaneous risk: there will be a more-or-less known distribution and actual losses will represent draws on that distribution. We will call this *Stage 2 risk*. If climate change is sudden and rapid, we may not place much confidence in our best estimate of the distribution, and I will refer to *Stage 2 ambiguity*. Thus *stage 2 risk* is the conventional insurance risk that underwriters will face in the future though, as I have indicated, future actuaries and modelers may be unusually challenged when it comes to estimating this distribution. If a conventional market with short term insurance contracts continues into the future, then contracts will be written based on the distributional information known at the time.

- Those exposures for which risk has increased (decreased) will face higher (lower) premiums.
- if the correlation amongst risk increases, insurance supply may be more constrained or contracts will be re-written to separate idiosyncratic and systematic risk. Such contracts will essentially mutualize risk.
- If there is considerable ambiguity, then insurers may require more capital
- Insurers will rebalance their exposures as the geographical exposures shifts

Stage 1 risk . Let me first be clear about what *Stage 1* risk is *not*. If there is a general upward drift in hazard; i.e., the best guess at the *stage 1* path is upward, then people do face an increasing hazard cost which will be manifest in both increasing insurance premiums and declining asset prices. These are real costs but they are not risk. Rather, the *stage 1* risk relates to the *uncertainty in the path* assumed by the *stage 2* risk. More specifically, it refers to the uncertainty in evolving *knowledge* as to how future risk is changing. However, that evolving knowledge will impact real decisions and will coalesce into real changes in wealth. The main *stage 1* risks will be the risk of volatile premiums, volatile asset prices, and volatile tax liabilities.

- If we assume that the market for insurance continues to be one with short term insurance contracts, then *stage 1* risk implies that future insurance premiums will be random. Premium setting will follow a Bayesian updating pattern. However, rapidly evolving climate risk, as revealed by actual losses, can lead to violent shifts in estimated future losses and therefore in premiums. The premium risk could be very severe.
- The second major form of *stage 1* risk lies in asset price risk. Assets that are exposed to a changing risk will be re-priced. For example, coastal homes will tend to devalue as the risk is perceived to increase. The price re-adjustment will reflect either the drag of expected future premium increases that accompanies ownership and/or the expectation that the owner will be faced with higher self insured losses.
- There are other forms the *stage 1* risk could assume. For example, if, following the Samaritan's dilemma, future governments bail out uninsured property owners, then climate change implies as random tax liability to fund these bailouts.

These are real risks to real people who, if they are risk averse, will seek to hedge. In particular, there may be a demand to insure these risks. I will focus only on two of the *stage 1* risks for insurance; the insurance of risky premiums and risky asset prices. However, to explore the potential for insurance, we need to be more specific about the generic properties of the *stage 1* (and *stage 2*) risks, and what these properties imply for the feasibility and design of insurance contracts.

While we know relatively little about the properties of *stage 1* risk, some conservative conjectures can be offered on properties that are relevant for risk management contracting. First, there seems to be a general (perhaps a better word is vague) consensus that the trend is upwards. Prediction of the impact of climate change on future tropical storm risk is difficult. Nevertheless, the general view is that global warming will lead to more intense (though not necessarily more frequent) tropical storms in some regions.^{4,5} Note that, insofar as an upward trend is expected, wealth transfers associated with this trend are not amenable to normal risk transfer mechanisms. Rationally, the expected increase in risk should

⁴ The Stern Review, "The Economics of Climate Change", Chapter 1.

⁵ The science behind this hinges on the interaction of three main effects, ocean surface temperatures, vertical wind shear and atmospheric humidity, but these may not all act in the same direction. For example, while higher water temperatures and higher humidity can increase the intensity of cyclones, increased vertical shear may tend to destroy the vortex and thereby break up the storms. See "Hurricanes in a Warmer World", Union of Concerned Scientists, 2006

already be impounded in house prices. Moreover, the expected increase hazard risk in a given region translates into an expected increase in insurance premiums.

A safer conclusion one can draw is that while the mean predictions of future regional storm activity are unclear, the confidence intervals surrounding those predictions are likely to increase. This uncertainty or ambiguity could be transferred under a hedge or insurance contract; clearly recognizing that the risk to be hedged is the deviation of the revealed path from the expected path. I.e., one might contemplate an insurance against *unanticipated* premium increases. However, the availability and pricing of such mechanisms might depend on whether the ambiguity is serially and contemporaneously correlated. Momentum in the hazard path implies greater variation in the long term hazard and diminishes the possibility of inter-temporal diversification.⁶ With such correlation, we could find that if we underestimated hazard risk for year, t , then likely we will have underestimated for $t+1$, $t+2$, etc.. In addition, there might be contemporaneous correlation. Suppose that nature chooses a general path for climate change (e.g., a 2° increase in mean global temperature over a 50 year horizon). With such a path, how correlated will the impacts on different hazards in different regions? If storms will be more severe/frequent in some areas and less severe/ frequent in other regions, then this ambiguity is diversifiable. Regional correlation however, diminishes the effectiveness of insurance and/or will increase its price. Similarly, will the chosen path simultaneously increase most risk types; storm, flood, drought, etc.. Again, correlation will degrade the effectiveness of risk transfer mechanisms.

ALTERNATIVE DISPOSITIONS OF STAGE 1 RISK

Stage 1 risk is uninsured and Stage 2 risk is insured through short term insurance contracts

In other words, insurance contract design remains as is. Of course, while contracts may continue to look as they do at present, climate change may still offer enormous challenges to insurers. Increasing risk will require more capital; and climate instability will lead to problems in estimating contemporaneous loss distributions and therefore difficulties in setting premiums. Bayesian updating of loss distributions from rapidly evolving hazard levels, could lead violent premium changes, and this premium volatility is a risk that lies with policyholders. Compounded difficulties would arise if, perhaps due to holding priors of differing volatility, policyholders and insurers differed in their Bayesian updating which could in turn lead to excess supply or demand. Additional challenges are faced if climate change leads to changes in the correlation structure of the world insurance portfolio (for example would El Nino/La Nina be shifted).

A different set of challenges to continuing short term contracting can arise from regulation. If, as suspected, premiums are on a rising trend, superimposed with sudden adjustments, there will be a popular demand for regulators to constrain premium increases. The lobbying will be further fueled if home prices are declining as a result of increase in hazard. Insofar as regulators are able to achieve rate suppression, without insurers withdrawing from the market, this will be in effect, an involuntary

⁶ This is a tricky issue. Paul Samuelson's well know paper, (Risk and Uncertainty: A Fallacy of the Law of Large Numbers, *Scientia*, April/May 1963) cautions of the pitfalls in repeated gambles and cautions on how far risk can be diversified through inter-temporal mechanisms

insurance of the *stage 1* risk. We have indeed seen many examples of rate suppression, either directly through the rate approval process (prior approval) used in many states, or in the formation of residual insurance markets, state run insurance pools. An example is Florida's current state reinsurance program which aims to hold reinsurance prices artificially low but which retains the right to levy *ex post* assessment on insurers (or increased taxes on residents) for any deficit.

Stage 1 risk is insured in constant premium long term insurance contracts

Can insurance cover both the *stage 1* and *stage 2* risks?. A paper by Howard and his colleagues, Erwann Michel-Kerjan and Dwight Jaffee advocates long term, constant premium, insurance.⁷ To be fair, they do not specifically advocate this structure for climate change. However, it is clear that its potential value of their long term contract rests on the instability of future hazard; and climate change is indeed such a context. The appeal lies on the demand side of the market where risk averse people would clearly benefit from offloading the joint risks of actual losses, volatile premiums and the future availability of insurance.

The problems lie on the supply side. Howard, et al, cleverly link insurance to pre-existing long term contracts which are rooted in value, i.e., mortgages. In doing so, they acknowledge that lenders already accept a long term risk position insofar as the revealed risk (either decline in house prices or uninsured losses) will affect their collateral. Could one go further and formally establish a market for long term constant premium insurance contracts?

Of course, there is a precedent. Life insurance is routinely sold on 20, 30, etc., year terms with uniform premiums. Thus, compared with short term insurance, policyholders are protected from the both the predictable upwards trends in premiums as mortality rises with age; and the unpredictable increases in premiums with random health events. This works well because of three factors. Mortality risk is pretty much known and actuaries can be confident in getting the premiums right. Second, the general trend in mortality risk has been positive; such surprises that have transpired in mortality have been benign - people are living longer. And third, while epidemics do sometimes occur, health events are mainly idiosyncratic and are pretty much randomly spread across the population. Thus, the two forms of risk insured by long term life insurance, premium risk, and mortality risk, are both easily estimated and diversifiable.

Comparing life insurance with long term catastrophe insurance is alarming. The three conditions which facilitate long term life insurance, predictable risk, uncorrelated trends in risk, and a beneficial trend in risk, are unlikely. If, as one fears, the upward trend in catastrophe risk, is associated with (serially and contemporaneously) correlated ambiguity, then the *stage 1* risk would not be amenable to diversification. If so, the amount of insurer capital required to secure that risk at an acceptable credit rating could be enormous. Insofar as the pool was not adequately prefunded with capital, then credit quality would deteriorate perhaps to the level of unacceptable counterparty risk.

⁷ Dwight Jaffee, Howard Kunreuther and Erwann Michel Kerjan, 2008, "Long Term Insurance for Addressing Catastrophe Risk" Working Paper # 14210, NBER.

I will mention another issue which is addressed by Howard et al. Unless such contracts are binding on policyholders, then competing insurers offering short term contracts can pick off those policyholders for whom risk might decrease. Such slippage will, of course, diminish the degree of risk pooling. This issue will bedevil most long term solutions including the following. A different approach to long term insurance contracts, is to optimize separately on the *stage 1* and *stage 2* risks.

Stage 1 risk is mutualized in binding long term contracts with separate treatment of stage 1 and stage 2 risk.⁸

Let me assume that *stage 2* risk is reasonably well behaved in the sense that it is not highly contemporaneously correlated across regions and insurance markets can secure geographical diversification. This is a strong assumption but I simply want to establish the minimal conditions under which short term insurance would function. Now let me assume that *stage 1* risk is subject to serial and contemporaneous correlation. To the extent that it is, diversification does not help. However, we know much about insurance design under such circumstances. Following Karl Borch's well known mutualization principle, (which presaged the capital asset pricing model), risk can be desegregated into idiosyncratic and systematic. The mutual structure allows all idiosyncratic risk to be effectively insured. However, the systematic risk is shared by all policyholders through equity participation (with accompanying dividends) in the overall risk pool. This can be achieved by organizational structure (mutual or reciprocal insurance companies) or by contract design (participating policies issued by a joint stock insurance firm).

Following this reasoning, one might conjecture that an optimal long term insurance contract would have the following structure. First, idiosyncratic and diversifiable *stage 1* premium risk would be mutualized. Each policyholder would have his premiums indexed to changes in the total risk in the pool. This would both ensure overall premium adequacy (total premiums would evolve in line with estimated total risk), and provide some degree of risk protection for those in regions where risk increased more rapidly (albeit unexpectedly so). *Stage 2* risk would then be insured under normal conditions. In short, the *stage 2* risk would be borne in the usual way by exposing insurer capital in the usual way; the *stage 1* risk would be borne communally by means indexed premiums. However, if it did transpire that *stage 2* risk started to exhibit higher correlation, then one could have a secondary level of mutualization under which all policyholders funded actual deficits (or shared surpluses) in the annual results by means of retroactive dividends.⁹

⁸ Karl Borch, 1962, "Equilibrium in a Reinsurance Market" 1962, , *Econometrica*, Vol. 30, No. 3., pp. 424-444. Also Georges Dionne and Neil Doherty, 1993, "Insurance with Undiversifiable Risk: Contract Structure and Organizational Form of Insurance Firms", *Journal of Risk and Uncertainty*, 6, 187-203.

⁹ However, if it did transpire that *stage 2* risk started to exhibit higher correlation, then one could have a secondary level of mutualization under which all policyholders funded actual deficits (or shared surpluses) in the annual results by means of retroactive dividends

An issue that arises with both this semi mutualized insurance, and the constant premium contract, concerns the incentives provided for mitigation. In either form, policyholders are protected from, at least, idiosyncratic changes in risk. Would this erode the desire to mitigate? Certainly, either form would compromise incentives for short term mitigation. As for long term mitigation the issue is more complex. Perhaps the central issue is that incentives for mitigation rest largely on the prospect that home values do indeed reflect risk. If long term insurance were bundled with home ownership (such that rights to the policy transferred with ownership of the house), then insurance would provide a hedge against falling house prices due to increased hazard. However, it is apparent that decoupling house prices from hazard risk would simply encourage people to continue to locate in high risk areas. Under normal insurance practice, the policy attaches to the policyholder not the home, so this may not be an issue. However this illustrates that addressing moral hazard requires that policyholders bear some risk.

Stage 1 risk is hedged through non-insurance mechanisms

The benefits a mutual approach to the *Stage 1* risk could be achieved by non-insurance mechanisms. Recall the claim that house prices will reflect changes in hazard risk. Consequently, one should be able to hedge against local changes in insurance premiums caused by changes in local risk, by taking derivative positions in house prices. A derivative trade in which one takes a short position in the house prices in one's home region, relative to the national change in house prices, should protect against the idiosyncratic *stage 1* risk. Moreover the aggregate balance of such positions would be zero (i.e., the risk is mutualized). There is an existing trade in house price futures on the Chicago Mercantile Exchange. Contracts can be bought on ten metropolitan areas, each based on the index of house prices in the chosen city. Changes in house prices in a city will reflect many influences including, as we speak, the general sub-prime decline, and regional changes such as regional unemployment and changes in regional hazard. Thus, in a chosen city, an owner can get some protection against declining house prices by selling forward on the CME contract for that city. This, of course bundles protection against all declines in house prices. Moreover, such trades would not mutualize the risk. To do this, one would need to sell forward on one's home city and buy forward on the national index.

The same effect can be achieved in principle with weather derivatives. While these derivatives are usually designed to payout on weather events, their prices will reflect local risk. A similar local-short/national-long strategy based on derivative prices should be able to isolate the deviation of the change in local risk relative to the overall change, thus mutualizing the risk. Doing this on weather derivatives provides more focus than with house price indices; it isolates the weather risk. However, the problem with both strategies lies in the term of the contracts. To be effective in hedging global climate change, the derivative strategy needs to cover the longer term impact on insurance risk and futures contracts spanning decades are not available.¹⁰

¹⁰ House prices should rationally impound changes in knowledge of future risk (not simply the change in risk itself). Thus a short term derivative could capture the impact of long term change, if the science on global warming were to improve dramatically, i.e., during the term of the derivative. This seems unlikely. Short of this happening, a second best strategy is to rollover the futures position as it becomes due. However, this exposes the hedger to refinancing risk.

CONCLUSION

The idea of writing long term contracts to insure both the realization of risk and the premium volatility (and availability) is an interesting, but a troubling one. Insurance markets are quite effective at writing short term contracts for catastrophe risk despite the problems they face. Even with short term contracts, there are problems enough; notable correlation and changing risk. However, insurers are finding ways to deal with these by clever modeling of risk, and innovative hedging instruments that economize on costly capital. By a clever mixture of reinsurance and insurance linked securities, insurers have made catastrophe coverage available despite the heavy concentration of insurance risk in a few locales such as the US east and west coasts, Europe, East Asia, Australasia.

Suppose that long term insurance is promoted, and with that promotion, an expectation from regulators and policymakers that it is to be widely available. If this insurance is offered with constant premiums, then it will require considerably more capital and that capital will need to be provided up front. Just how much extra capital depends on how risky is the *stage 1* risk. If indeed this risk has not only high variance, but also serial and contemporaneous correlation (as seems plausible), then the increased capital required could be multiples of that required for corresponding short term insurance. This would imply either that

- Very little long term insurance could be supported by a given capital base
- Long term insurance would be subject to large credit risk
- Or that innovative instruments designed to securitize the *stage 1* risk would emerge (however, these would also create their own capital demands)

The danger is that, with scarce and costly capital, insurers could either offer a limited supply of long term constant premium insurance that was subject to serious credit risk; or provide a large capacity of more conventional short term insurance subject to acceptable credit risk. It seems to me that the latter is a better use of insurance capital. Indeed, if the risk of realization of loss is indivisibly bundled with the risk from premium volatility, then I fear that less, rather than more, insurance would be available. The enormous capital demand required for ensuring constant premiums and guaranteed availability, would crowd out capacity for insuring the actual losses. Better let insurers do what they are good at, than divert them into contract structures that encounter unknowable long term risks. Indeed, I fear that such contractual commitments could create the insurance equivalent of the current sub-prime debacle.

The theoretical roots of this discomfort with constant premium long term insurance, is simply that it is a sub optimal form of risk sharing. If my conjecture that stage risk exhibits unusually high ambiguity, then the optimal sharing of risk follows a different structure; *stage 1* risk being mutualized as a communal burden; and *stage 2* risk covered from insurer capital in the usual way. However, I freely concede, that even this more restrained form of long term contracting, would face problems of contract enforceability and needs further scrutiny for moral hazard incentives. If the risks of climate change are to be addressed, we simply cannot have the population being subsidized for choosing to live in high risk areas. Any attempts to protect people from long term risk can create such subsidies and need to be treated with serious caution.