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# ADAPTING MORE CLEVERLY TO CLIMATE CHANGE BY USING 'REAL OPTIONS' TO ADDRESS THE UNCERTAINTIES.[1]

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**Abstract** Scientists consider that some climate change is already inevitable, even if anthropogenic greenhouse emissions are stabilised immediately. Adaptation measures are therefore needed, irrespective of any mitigation action. But policy discussion is focussed on deterministic responses, generally risk-based 'worst case' scenarios. An example is the development of more stringent standards for buildings and for coastal development. Such 'climate proofing' is misconceived in the face of the huge uncertainties involved. Economists need to promote more rational policy frameworks that draw on cost-benefit analysis, including the use of 'real options' to minimise the cost to society of adapting to climate change.

## Introduction and background

Although some government agencies took note of climate change issues and their potential implications at least as far back as the early 1980s, the first major engagement of the Australian Government in the area was not until 1990. In October of that year, the Minister for Arts, Sport, the Environment, Tourism and Territories, Ros Kelly, and the Minister for Primary Industries and Energy, John Kerin, jointly announced that the Commonwealth Government had adopted an interim planning target to reduce emissions of greenhouse gases by 20 per cent by the year 2005. They also commissioned an Industry Commission report that was published the following year.

The National Greenhouse Response Strategy (NGRS) that was published by the Commonwealth of Australia (1992) with the endorsement of the Council of Australian Governments (COAG), following consideration of the issues by a series of working groups on ecologically sustainable development, addressed for apparently the first time the issue of adaptation to climate change. The strategies for protecting 'Australia's natural, human and built environment from the potential impacts of the enhanced greenhouse effect' included:

- conducting research into the potential impacts of the enhanced greenhouse effect, including development of techniques to assess vulnerability;
- assessment of the vulnerability of the natural, built and human environment to climate change;

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- incorporation of planning for possible impacts of the enhanced greenhouse effect into existing conservation and planning strategies;
- incorporation of information on the potential impacts of the enhanced greenhouse effect into disaster planning; and
- ensuring that natural resource management (e.g. agriculture and forestry) regimes take into account the potential impacts of climate change.

In 1998 the NGRS was reformulated into a National Greenhouse Strategy, but the issue of adaptation to climate change was largely ignored for a decade after the Howard Government came to power. In February 2006, (COAG) agreed to a Climate Change Plan of Action, with endorsement of a National Climate Change Adaptation Framework at its April 2007 meeting.

As one of its last acts before it lost the general election in 2007, the Howard Government announced the establishment of a Climate Change adaptation centre at Griffith University. Located at the Gold Coast campus of the university, the National Climate Change Adaptation Research Facility (NCCARF) will operate in partnership with seven other universities and the Queensland Government. The Director of the NCCARF, Professor Jean Palutikof, is reported in *The Australian* of 14 January 2009 as saying that 'the field of adaptation research [is] not well advanced and the emphasis would be on developing resilience' (http://www.theaustralian.news.com.au/story/0,,24909483-12332,00.html?from=public_rss). Her comment echoes that of Schneider et al (2007, p. 797) who recognise that 'the scientific literature [on adaptation] is less well developed than for mitigation, and the conclusions are more speculative in many cases'.

This paper argues, in necessarily abbreviated form, that:

- scientific and engineering perspectives are generally risk-based but lack sufficient information and may therefore result in misguided policy formulation;
- standard cost-benefit analysis based on scenarios is also effectively deterministic in nature;
- strategies for adapting to climate change cannot be based on risk-based methodologies because of the significant uncertainties involved in timing and intensity of any change; and
- if Australia is to minimise the costs of adapting to climate change, policy formulation must be based on cost-benefit analysis that takes into account available 'real options'.

## Mitigation versus adaptation

The term 'mitigation' is used in this paper to mean reductions in the emission of greenhouse gases from anthropogenic sources such as power stations or agricultural production. Its primary aim is to mitigate or ameliorate the contribution of anthropogenic greenhouse emissions to total atmospheric concentrations.

Adaptation, by contrast, refers to deliberate efforts to obviate or ameliorate the physical effects of a changing climate. For example, the building of sea walls to control flooding from rising sea levels. Adaptation does not (repeat not) refer to structural adjustment to mitigation measures such as carbon taxes or targets for producing energy from renewable sources. That

is, adaptation does not refer to lower consumption of fossil fuels due to higher petrol prices engineered by governments.

It is immaterial to the argument in this paper whether measures to adapt to a changing climate are taken because climate change is due to anthropogenic causes or to natural phenomena or both.

**Analytical frameworks in the area of adaptation**

Considerable work has, and is being done by the scientific community to identify the likely extent and effects of climate change. Much of this work is reported in publications such as Intergovernmental Panel on Climate Change (2007). Despite the best efforts of climate modellers, however, there is still much uncertainty about the nature and extent of climate change at the local level. For example, Hennessy et al (2007, p. 529) acknowledge that:

> 'Assessment of impacts is hampered because of uncertainty in climate change projections at the local level (e.g. in rainfall, rate of sea-level rise and extreme weather events). ... Other uncertainties stem from an incomplete knowledge of natural and human system dynamics, and limited knowledge of adaptive capacity, constraints and options. .... More needs to be done to assess vulnerability within a risk-assessment framework.'

The engineering fraternity has also adopted a similar 'risk management' methodology in tackling the issue of adaptation to climate change. For example, the Australian Academy of Technological Sciences and Engineering (2008, p. 21), states that a methodology is required 'which enables risk to be determined in a systematic and scientifically based manner'. It sees the use of Australian Standard AS/NZS 4360:2004 Risk Management as the key, but also acknowledges (p. 22) that 'caution is advised in the assessment of likelihood, since it must be recognised that the scenarios are projections based on a range of models and future emission assumptions'.

Given the difficulty of obtaining accurate projections at a local level of the effects of climate change, it is at least arguable that the risk-based approach adopted by scientists and engineers, and currently accepted by governments, is a sterile methodology. It cannot indicate the optimum amount of adaptation that should be undertaken and often merely resorts to recommending action to overcome broad risks such as flooding or heat waves or rising sea levels. But such recommendations are insufficiently specific for policy formulation. For example, how high should sea walls be? Nor do such recommendations provide much sense of timing: when exactly should we start to build sea walls?

A good example of the contradictions inherent in using a risk-based approach in the absence of accurate information about the likelihood of the risks is a report by Voice et al (2006) on the construction of a wharf and coal terminal at Port Abbott in Queensland:

> 'While specific case studies of the vulnerability of ports to climate change have not been performed, ports have generally used the National Committee on Coastal and Engineering guidelines ... to make allowance for climate change effects. ... Major new port infrastructure is thoroughly assessed for the impacts of climate change in the design phase. ... For example, the proposed new offshore wharf structure and expanded coal terminal in the Port of Abbot Point in Queensland ... studied a number of greenhouse potential impacts. The new facilities were designed for expected water level changes predicted over the next 100 years (conservatively estimated at 0.2 metres to 0.5 metres) ... New port infrastructure therefore is well prepared for the impact of climate change.' (section 6.3.2, pp. 50-51)

At worst, the risk-based approach will lead to planning on the basis of worst case scenarios to provide a sense of certainty to decision-makers. Should this be the case, and actual climate

change not meet worst-case expectations, considerable resources would be wasted. Conversely, if the extent of a worst-case climate change effect is underestimated, and a sea wall is built too low, unnecessary damage will be incurred by the community.

Cost-benefit analysis

Analysis of potential mitigation measures has been effected through cost-benefit analysis for some time. A prominent early example is Nordhaus (1991). Cost-benefit analysis is probably the most appropriate tool available in this context, but it suffers from two key drawbacks. From a national perspective, the costs of mitigation are relatively easily estimated, but benefits are not, because they are shared jointly by all countries. So it is conceptually difficult for any one country to compare the costs and benefits of mitigation strategies. The second problem relates to discounting over a very long period that may span many generations into the future. Even where it is agreed that intergenerational discounting should be carried out, the discount rate itself is contentious.

At first glance, the application of standard cost-benefit analysis to adaptation measures appears to be more straightforward. The national resource costs of building a sea wall, for example, can be estimated with reasonable accuracy, and any benefits (in terms of damage avoided, or in terms of willingness to pay if data are available) can be attributed directly to Australian residents or citizens alone. Further, the issue of intergenerational discounting does not arise as intensely because infrastructure like sea walls, while long-lived, can be considered within a well-explored debate about the most appropriate discount rate. Although the actual discount rate may still be contentious, there is more likelihood of some degree of agreement on an acceptable range of values somewhere between a social rate of time preference and a social opportunity cost of capital.

However, the application of a standard cost-benefit analysis to adaptation issues faces the same methodological problem as the deterministic risk-based approaches adopted by scientists and engineers. Rudimentary cost-benefit analysis is based on discounting an identifiable stream of costs and benefits. But the fact that a specific stream of costs and benefits is identified implies that the future is known with certainty.

Some allowance can be made for uncertainty by attaching probabilities to different scenarios or outcomes. For example, scientific data may suggest that there is a 0.1 probability of mean sea levels rising 1 metre within a decade in Cairns, a 0.7 probability of a 2 metre rise, and a 0.2 probability of a 2.5 metre increase. The stream of expected costs and benefits can be represented on a decision-tree that incorporates these probabilities and a net present expected value obtained. But even this approach is effectively deterministic because it attaches specific, fixed probabilities to each scenario and therefore implies that the future is known with enough certainty to attach specific probabilities to events.

While it is possible that some modellers may be extremely confident about their ability to predict the timing and the extent of the effects of climate change (for example, specific temperature increases or storm surges in specific years), the likelihood of such accuracy is low. Even less accuracy is possible in forecasting specific effects at the local level (e.g. for a town like Ballarat) rather than regions or continents. Whether we like it or not, there is a great deal of uncertainty about the effect of climate change at the local level, where, by definition, any adaptation must occur.

It is the thesis of this paper that policy formulation in Australia should recognise explicitly the uncertainty inherent in forecasting localised climate change effects, rather than engaging in decision-making based on a so-called risk basis. Fortunately, the tools for doing so are readily available.

## Real options: the cleverer option

Ordinary investment decisions are routinely made in the face of uncertainty about future flows of costs and benefits. Recent events in international financial markets have demonstrated amply the degree of uncertainty that may exist, even if the ordinary punter does not foresee it. To assume certainty, or to base investments on an analysis of 'certain' flows of revenue and costs, can result in disastrous consequences for the individual investor. One common method of reducing the risk is to employ financial options rather than, for example, purchasing shares outright.

A financial option provides an investor with a right (but no obligation) to purchase a specific share at some specific future date at a specific price. This financial option costs the investor less to buy than the corresponding share. Once the pre-specified data arrives, the investor can decide whether or not to buy the share itself. If the price of the share is above the price previously specified in the option contract, then the investor has the opportunity to buy it at the contracted price and sell it for a profit because its price in the market is greater. If the share value has fallen below the option contract price, then the investor will probably avoid exercising his or her right to purchase the share at the contracted price because it can be bought more cheaply on the open market. Where the share price has fallen, the investor loses only the value of the financial options that he or she purchased in the past. The loss is limited, even if there is a dramatic fall in share market values.

In the realm of 'real' (i.e. physical rather than financial) capital, it may also be possible to create options when investing. An everyday example given in Dobes (2008, p. 62) is that of a couple buying a house, but uncertain about when, or if, they will have children, or how many children:

> 'Buying a large house immediately could be unnecessarily costly if they remain childless, or if they delay starting a family for a significant time. But they could buy a smaller, cheaper house on a suitable block of land and extend it later, as required. The smaller house in effect 'embeds' an option to extend, but there is no obligation to do so if the family remains small. The couple can delay a final decision on the size (and hence the full cost) of the house until better information becomes available regarding specific family size.'

The concept of 'real options' is more familiar to management theorists as 'strategic options'. For example, a firm may enter a joint venture or use business method patents: Raynor (2007); Nerkar et al (2007).

Dixit & Pindyck (1994, pp. 3-4) point out that most investment decisions share a number of common characteristics, including:

- the investment is partially or completely irreversible. That is, at least part of the initial cost is 'sunk' because it cannot be recovered even if the rest of the investment process does not proceed. If all costs were recoverable, there would be no value in delaying the full implementation of the investment.
- there is uncertainty over the future rewards or payoffs from the investment.
- there exists the ability or opportunity to delay the timing of the investment, at least partially.
- more information about potential rewards or payoffs (but never complete certainty) becomes available during any procrastination.

Dixit and Pindyck show that it is possible to include the value of real options in a cost-benefit context to take account of uncertainty about future values of costs and/or benefits. Often, projects may appear to be unviable (NPV < 0) using standard cost-benefit analysis where it is assumed that full investment resources must be committed immediately, or not at all. However, a partial investment that creates the option (but not an obligation) of a fuller investment commitment later, when more information becomes available, may well yield a positive net present value.

The real options approach is particularly apt in the case of analysing adaptation to climate change. In particular, the future timing and intensity of climate change at the local level is highly uncertain so the future benefits of immediate action are not known, commitment of resources (e.g. building a sea wall) is at least partly irrecoverable, and delay in action is still possible, enabling better information to be collected.

## Applying real options to climate change adaptation strategies

The most difficult aspect of applying a real options approach to adaptation issues is the need for creativity and lateral thinking about specific situations in local settings. The following examples are intended only to be indicative of the general possibilities.

### Airport runways

If the climate becomes significantly hotter, planes will need a longer take-off to develop sufficient lift. (More powerful engines are an alternative, but they would also create more noise.) An airport owner considering the future might decide to build a longer runway now. But immediate construction would mean that the full cost would be incurred up-front and temperatures might not rise as fast or as high as expected on the basis of current knowledge.

In the face of uncertainty about the future, a better option for the airport owner would be to purchase or earmark additional land for a runway extension but to wait until temperatures increased significantly before undertaking its construction. An even better option would be to purchase a (financial) option to buy the land if temperatures rise by a specific date in the future.

Flooding in low-lying areas

Riparian flooding and inundation due to rising sea levels are commonly cited effects of climate change. The popular prescription is to build sea walls or levee banks to protect nearby life and property. However, such advice is rarely if ever accompanied by advice on exactly how high a wall or levee bank should be, or when it should be built. In the absence of information on likelihood of occurrence, this is understandable, but the policy risk is that advice will default to planning for a worst-case scenario. But a worst-case scenario can be unnecessarily wasteful of community resources, and even worst-case scenarios change over time as more information about climate change becomes available.

In the absence of reliable information about future river or sea levels, a cleverer option would be to build a solid base that is capable of supporting a high (worst-case or higher) wall, but only build a wall high enough to offer protection for current circumstances, or perhaps no wall at all. The wall can be raised later if the foundation is so designed, or the base can just be used for sandbagging for the occasional flood or king tide. Inflatable flexible PVC tubes (the so-called Beaver flood barrier, *Engineers Australia*, February 2009, p. 69) that are filled with water and can be stacked on top of each other provide a further option that is faster and easier to erect than sandbag barriers.

In other words, the option created by building only a base or low wall means that the full cost of a higher, worst-case wall is not incurred until it is actually required due to repeated and frequent flooding.

The floods in February 2009 that isolated Cairns from other coastal towns despite the recently upgraded Bruce Highway, saw calls for an even higher, 'flood-proof' highway, or an alternative inland route (e.g. editorial *The Cairns Post*, 11 February 2009, p. 12). A cheaper option that could have been used to alleviate the shortages of meat, milk and vegetables that were experienced by Cairns residents would have been to bring in more supplies by sea. However, a shortage of refrigerated containers apparently precluded this solution, and established supply chains on the part of major retailers such as Woolworths appear to have precluded use of local produce (*The Cairns Post*, 10 February 2009, p. 4). Nevertheless, it is clear that there are at least two real options (flexible local food purchasing arrangements and warehousing of 'spare' refrigerated sea-going containers) available as alternatives to immediate flood-proofing of the coastal highway.

'Fitted for, but not with': the military approach

Public transport may, in a hotter future, require better air conditioning, especially if it becomes more crowded, and certainly if it is to attract an increased patronage. But fitting stronger air conditioning units today may be unnecessarily wasteful if the current bus or train fleet is scrapped before temperatures rise significantly.

An option is to use the military approach of 'fitted for but not with': for example, a weapons platform like a ship may have space and wiring available for installing a missile system, but the missiles are not actually installed or used because they are too expensive under current threat scenarios. Installation and use occurs only once a threat scenario warrants their use. The option created by this delay can also have the benefit of ensuring that a future missile

system is designed to be capable of penetrating whatever future electronic or other anti-missile defences that an adversary may develop.

Trains and buses can similarly be 'fitted for but not with' stronger air conditioning units by designing space for future installation.

Long-lived infrastructure

The real options approach is particularly relevant to long-lived infrastructure such as roads or railways. A decision to build may need to be taken today, but the infrastructure will last well beyond the accurate time horizon of current predictions of climate change. We do not know, for example, how high the road should be above the surrounding land because we cannot forecast accurately the extent of any flooding along each section of the road.

A real option could be to set aside land additional adjoining a road or railway route to form a wider corridor. If required in future, the additional space can be used to build protective levee banks to protect the road or railway from flooding. Or gabions can be placed next to the road or railway to minimise damage from wave action, a solution that would be familiar in Queensland. And the costs of acquiring additional corridor space can be partly offset by leasing it to pipeline or telecommunications infrastructure providers.

Buildings

An Australian Government website admits that 'we are at an early stage in understanding likely impacts and options for dealing with them', but nevertheless encourages the public to adapt to climate change as follows:

> 'Early planning for the impacts of climate change is likely to bring considerable advantages. Many decisions made today will have consequences for decades. *It is cheaper, for example, to design new housing or infrastructure to cope with a future climate than to retrofit later*.'
> (http://www.climatechange.gov.au/impacts/howtoadapt/index.html; viewed 16 January 2009, emphasis added)

One can only speculate about the basis on which such advice is offered. Does it apply to all buildings, in all locations? What is the climate scenario envisaged? Is it a worst-case scenario, and which one? How much 'retro-fitting' would in fact be required? And if cities are to be redesigned or rebuilt at some stage in future to make them more compact or more amenable to greater use of public transport or lower greenhouse emissions, is it really financially prudent for an individual home owner to invest now in an expensive, climate-proofed house? And would the Government be willing to accept responsibility for any misplaced investment based on its advice?

Possibly counter-intuitively, it may in fact be cheaper from a national perspective to encourage the building of flimsy houses, and the reduction of maintenance on existing dwellings. Earlier scrapping of buildings offers greater flexibility, and hence more options, in terms of adaptation. Once the extent and nature of future climate change become better known, the most appropriate – and hence optimal in terms of cost – structures can be built.

One presumes that the Department undertook some careful calculations before proffering this advice. But what do such sums amount to in the face of uncertainty about the extent and timing of specific climate change effects for each locality in Australia? Is it really cheaper to build a house designed to withstand an absolute worst-case scenario (and which one?), or did the Department mean something less drastic? Indeed, it might in fact be even cheaper to build a flimsy non-climate proofed house now, and rebuild it, if necessary, once the true extent and timing of any climate change becomes much more certain.

A striking feature of the February 2009 flooding in north Queensland is the number of houses that were damaged due to water only about 1 metre high or less. There may well be lessons to be learned from historic building practice. Houses on stilts were built in the past to take advantage of cooler areas under the house, but also as a partial defence against flooding and the occasional crocodile or snake that sought higher ground. However, little consideration appears to be given currently to such possibilities.

And would it not be socially more desirable to keep current expenditure on housing to a minimum, in case cities need to be redesigned to take account of mitigation measures that reduce transport needs and increase housing density?

## Bushfires

Informed comment will need to await the findings of the Royal Commission appointed by the Victorian Government. But it is already clear that at least some of the tragic loss of life and property might have been avoided through options such as better education of residents, installation of fire shelters near houses (ditches covered with logs and earth were used in the nineteenth century but concrete pipes and brick rooms were used successfully in February 2009), or more frequent backburning of forest litter. All of these offer 'real option' alternatives to expensive construction of purpose-designed fire-proof (if such a things exists) houses now being proposed by some.

## Agriculture

Australian farmers have more than two centuries of experience with adaptation to climate change, and regularly use real options. A farmer who has prepared land for a cotton crop, for example, may keep in reserve the option of planting sorghum in a dry year.

The recent introduction of the South African Meat Merino (ABC, 2006) offers the option of producing meat or wool from the same animal, depending on weather and market conditions. And research into drought-tolerant grains continues to provide hope of adaptation through genetic engineering of crops.

And we should remember that Australia's legendary cattle king, Sidney Kidman, created real options for his herds by acquiring a string of contiguous properties across the continent. Dry conditions locally could be overcome by moving cattle to other properties with sufficient feed and water.

Health

Direct action may be possible in cases such as malaria or dengue fever, where they threaten (e.g. McMichael, 2004) to become increasingly endemic across Australia. Media reports (e.g. Beeby, 2009) of research at the University of Queensland, for example, suggest the possibility of using a bacterium to reduce the lives of a specific mosquito species to a level of immaturity at which it is unable to transmit dengue fever. Similarly, initial research at the University of Melbourne gives hope that the digestive system of the malaria parasite can be switched off chemically to starve it to death (*Canberra Times*, 4 February 2009, p. 3).

Research in itself is a real option. But it is possible that even cheaper real options may exist. For example, the *Cairns Post* (11 February 2009, p. 9) carries an uncorroborated report of an experiment by students at Cairns High School that shows that three mosquito traps placed in each household would be sufficient to prevent a major outbreak of dengue fever.

## Mitigation versus adaptation

Further consideration needs to be given to potential conflicts between policy on adaptation and on mitigation. Three examples of potential conflicts are given here:

- It is not clear what 'climate proofing' of houses means. The current trend to the installation of air conditioners, even if combined with improved insulation and energy-rated building standards, will result in greater emissions of greenhouse emissions.
- Greater use of air conditioners will also increase noise levels. At the margin, those who would normally rely on more vegetation and outdoor living to escape the heat, may well be driven indoors and subsequently install air conditioning themselves. Unless all externalities are addressed simultaneously, climate change policies may well prove to be distortionary or even self-defeating.
- Increased use of solar panels – currently encouraged by the various Australian governments – is envisaged as a means of reducing emissions. However, given the expected increase in frequency of hailstorms, it is not clear how effective solar panels can be when mounted on roofs. One option may be to cover them with protective mesh if hailstorm damage does indeed become more frequent.

## Conclusion

The real options approach is simply commonsense and is applied as a matter of course in many day-to-day situations by people who have never bothered to read the economic literature. However, it also makes sense from a policy perspective, and is highly desirable to avoid unnecessarily wasteful expenditure on the basis of worst-case risk-based scenarios.

My research to date has been limited to conceptual issues and the collection of examples of potential real options in the area of adaptation to climate change. The next step is to develop analytical frameworks that can be applied by policy-makers and planners to specific cases. Dissemination of ideas and techniques will also play a key role in assisting communities to adapt to local changes in climatic conditions, whenever they occur.

The author would welcome any contributions of other examples of the potential application of real options in the area of adaptation to climate change ( Leo.Dobes@anu.edu.au ).

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