

Towards economic and policy analysis of adaptation to climate change.

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Abstract

To date, most economists working on climate change have focused on mitigation policy. Economists generally see adaptation to the inevitable ongoing impacts of climate change as something that will occur autonomously throughout society. This mental model – adopted inadvertently – limits the role of governments to funding mostly science-based R&D to close perceived knowledge gaps for a private sector that is assumed to be ready and willing to adapt. Economists who have worked on adaptation at all have tended to focus on valuing specific adaptation options, or appropriate valuation methodologies.

In this paper we argue that economists urgently need to re-examine the economic nature of climate change adaptation as a public policy agenda. We provide a simple analytical framework demonstrating that pro-active, anticipatory adaptation is likely to be economically more efficient than reactive adaptation because it increases opportunities for flexible and low cost adaptation. We note that there is mounting evidence – such as in the aftermath of the Victorian bushfires and Queensland floods – that autonomous adaptation tends to be reactive and ad-hoc rather than proactive and anticipatory.

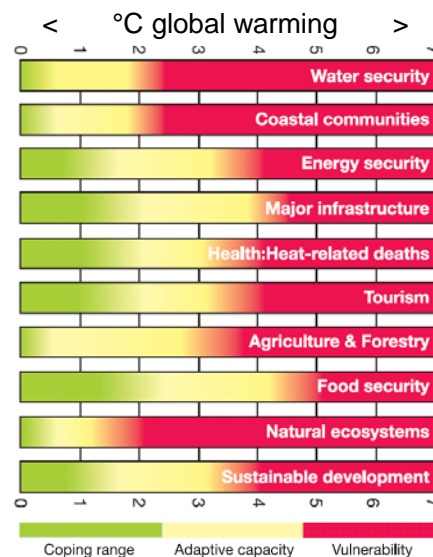
We then propose that there are market failures much more persistent than simple knowledge gaps that systematically work against early precautionary adaptation, particularly adverse selection and moral hazard. In a manner which in some respects echoes health policy, there is a potential role for governments in overcoming these, to reduce both personal catastrophic losses and national losses of efficiency and productivity. We conclude that only by thinking through the economic nature and dimensions of adaptation can we arrive at robust criteria for assessing questions such as the appropriate role of government, selection of appropriate policy instruments or choices of appropriate valuation methods. A goal of adaptation policy might be to identify policy options with potential to overcome these identified market failures, and so achieve a more appropriate mix of adaptation that anticipates future change, and less maladaptation, than would otherwise be achieved by imperfect markets.

1. The Adaptation Challenge

According to the Australian Treasury's 2010 intergenerational report *Australia to 2050: future challenges*, climate change is “the largest threat to the environment and represents one of the most significant challenges to economic sustainability”.

The adaptation challenge will be significant whether we face a future that on average is 2°C or 4°C warmer, but the nature of this challenge may differ dramatically. With a 2°C rise in mean temperatures, most sectors will be stressed but able to cope. Exceptions include water security (which has already led to significant investment in desalination plants), coastal communities (where local governments are already on high alert) and ecosystems (which will be vulnerable because coping capacity is limited). A 4°C average increase in global temperatures is outside the current coping capacity of many sectors – into the red zone in figure 1.

Figure 1 – Vulnerability to climate change in Australia and New Zealand.



Source – IPCC Working Group 2, Chapter 11

The potential for serious, if not catastrophic, impacts provides a sense of urgency for action on adaptation to climate change. Estimates of the value of assets and infrastructure exposed to these impacts, and potential declines in production due to unmitigated climate change, are only approximate measures of what is at stake in adaptation across most sectors and regions of Australia.

While some of these impacts will be managed as a normal part of business, most sectors undertake investments with lifetimes that reach well into the future periods in which they will be affected by climate change. Without early adaptation to anticipate future change, these decisions are likely to have costly implications in the future. Ongoing research is developing case studies indicating the value of early adaptation to avoid future costs and, in some cases, allow the take up of new opportunities. For example, research in progress by CSIRO's Climate Adaptation Flagship shows that:

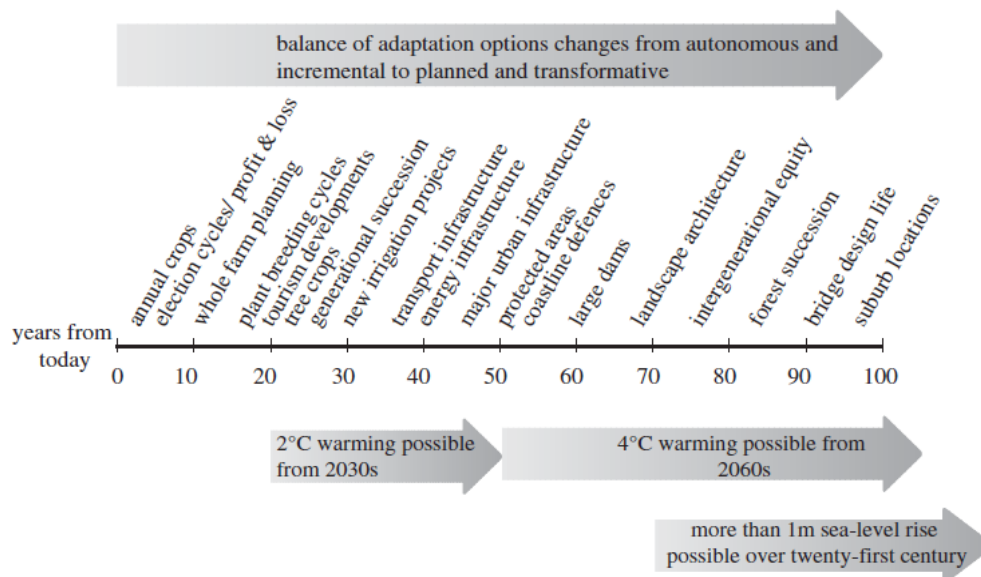
- *Inundation risk to households.* In south east Queensland the net present value to 2030 of preventing new development in areas that will later be at greater risk of

inundation has been estimated to be at least \$0.8bn (and probably several billion dollars). This value would be multiplied many times if this research was extrapolated around Australia's national coastline, and taken out to 2100.

- *High wind risk for new housing.* The net present value to 2100 of appropriate increases in wind classification for new housing in cities is at least \$8 billion. This value declines rapidly if action is delayed to 2020 or 2030.

The need for early action is greatest for decisions with long lifetimes, and these can be systematically identified across sectors (figure 2). Long lifetime decisions can be contrasted with short lifetime decisions, such as choosing the crop variety for next year's agricultural plantings, which do not need urgent action. Long lifetime decisions often concern assets which tend to be seen as a government responsibility after decades have passed, even if they were initially private sector investments.

Figure 2: Lifetime of different types of decisions (Stafford Smith 2011).



2. Conventional Approaches to Adaptation and Adaptation Policy

The international literature on *adaptation* to climate change is thin – remarkably so compared to the literature on its twin, *mitigation*. The typical approach in the few countries that have given much thought to it has been strikingly linear: scientists predicted future climates regionally; hazards and vulnerable sectors were identified; engineers and coastal/urban planners devised ‘solutions’ to respond to the perceived risks; and governments tried, by whatever means, to have these ‘solutions’ implemented, typically by the private sector and local governments. The typical role of government suggested was either to fund more science, to disseminate more information, or to regulate activities in vulnerable sectors and regions. In Australia, the 2007 CoAG *National Climate Change Adaptation Framework* is very much in this model.

In their recent survey article, Fuenfgeld & McEvoy (2011) distinguish four commonly used framings of adaptation: Hazards Approach; Risk Management Approach; Vulnerability

Approach; and Resilience Approach. While all of these approaches have merit, none of them includes rigorous economic analysis.

Few economists have focussed on Adaptation to date. The dominant approach among these few has been to apply conventional risk-management techniques and Benefit-Cost Analysis to assess the merits of alternative investment options under a narrowed set of probabilities (World Bank 2009, Hallegatte *et al*, 2011). A more nuanced approach has been to apply theories of “Real Options” and a portfolio of adaptations (eg Dobes 2011).

Only a handful have focussed on the economic dimensions of the adaptation decision, and the market failures that deter and impede adaptation (e.g. Dannenberg *et al* 2009; Osberghaus *et al* 2010). Aaheim and Aasen (2008) also argue that people and companies *will* adapt autonomously, but that such autonomous adaptation is not always ideal. They noted:

‘If all economic transactions were carried out as explained in economics textbooks in which markets are perfect and economic agents respond consequently and immediately to shifts in the environment, the best and most efficient way to adapt would be to let each and every one take his/her responsibility and act according to his/her own beliefs. Public bodies and proactive public strategies for adaptation would be superfluous, in principle.

However Garnaut (2008, p 33) asserted that ‘adaptation policy differs from mitigation policy in that there is no immediate or obvious missing market or market failure’– adaptation will occur spontaneously in response to market forces as households and businesses reach their own independent decisions in their own self-interest. Furthermore, (Garnaut, 2008, p 363)

The appropriate adaptation response will always depend on a range of local circumstances. Therefore, unlike the mitigation effort, adaptation is best seen as a local, bottom-up response. Households, communities and businesses are best placed to make the decisions that will preserve their livelihoods and help to maintain the things they value.

Following Garnaut, the Australian Government’s 2010 position paper *Adapting to Climate Change in Australia* assumes that adaptation will occur autonomously throughout society given an appropriate mix of incentives, including a regulatory environment that facilitates adaptation, appropriate allocation of risk, and a suite of policy instruments for use where market mechanisms are ineffective. The position paper defines the role of the Australian and State governments as

- (i) providing information for business and communities to adapt,
- (ii) setting the right conditions for businesses and communities to adapt, and
- (iii) managing government programs and assets in a way that recognises the impacts of climate change.

The specific roles for the Australian Government include *maintaining a social safety net, leading national (regulatory) reform, and managing Commonwealth assets and programs.* However, implementation to date has focused mostly on *funding national science and information.*

The position paper underestimates the degree of market failure and hence the magnitude of policy reform needed to ensure **appropriate** adaptation.

3 The nature of adaptation

Adaptation involves taking action to manage the impacts of climate change so that current goals can continue to be met, and/or realistically adjusting goals as climate change influences opportunities and constraints. A dominating feature of adaptation is that the specific objectives of adapting vary for different groups throughout society depending on local circumstances. Adaptation has therefore been rightly described, by Garnaut and others, as very context- and location-specific. This also means that in many cases, Governments can only indirectly monitor and influence adaptation outcomes.

However, adapting *effectively* means taking action appropriate to the nature of change being experienced, and this action can be undertaken before or after change occurs. Actions that are inappropriate or poorly timed are likely to result in *maladaptation*. Maladaptation can result in a spectrum of outcomes ranging from foregoing worthwhile opportunities to adapt more fully, to outcomes worse than the untreated impacts of climate change.

Adaptation action is *appropriate* if it is commensurate with the nature and magnitude of the impact it is intended to manage. Adaptation responses misdiagnosed as predictable or ‘small relative to adaptive capacity’ may obscure the need for more transformational actions and lead to under-investment that later proves costly. Conversely, adaptation responses misdiagnosed as uncertain or ‘large relative to adaptive capacity’ are likely to be costly and absorb resources needed for adaptation elsewhere.

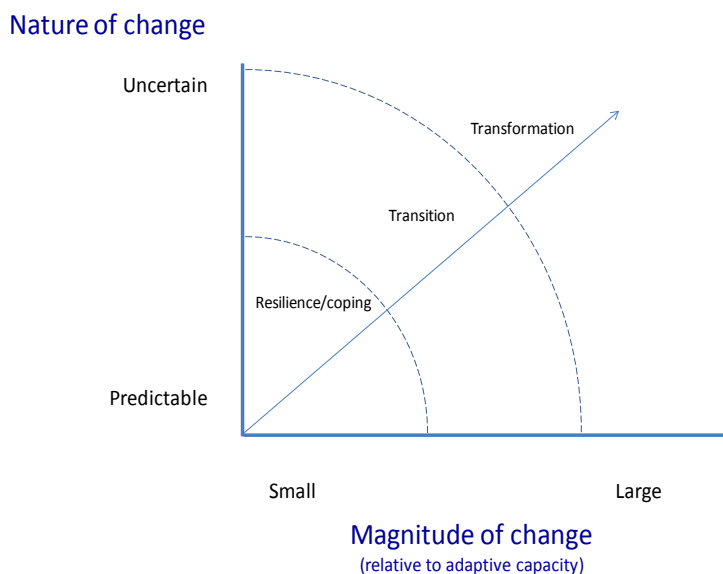
The nature of appropriate adaptation actions depends on the nature of impact – particularly its predictability and magnitude relative to adaptive capacity (Pelling, 2010) (see figure 3).

- Incremental adaptation (also known as coping or resilience) – for impacts that are predictable and/or small relative to adaptive capacity - current goals can be pursued reasonably unchanged within existing ways of doing things.
- Transitional adaptation – for impacts that are only partially predictable and/or is significant relative to adaptive capacity - existing ways of doing things need to operate at close to their full potential in order for current goals to remain reasonably unchanged.
- Transformational adaptation – for impacts that are uncertain and/or exceed adaptive capacity - adaptation requires fundamental modifications to the ways things are done and/or significant adjustment to current goals.

Adaptation can be undertaken before or after change occurs. For predictable and small impacts, it makes little or no difference whether adaptation is implemented before or after change has begun to occur. But for uncertain and large impacts, it may be essential to transform well before significant change occurs, to increase opportunities for flexible and low cost adaptation.

In practice, adaptation occurs through the actions of diverse stakeholders throughout society including individuals, households, communities, businesses and governments. These stakeholders take action at different scales to meet multiple, interacting, and changing goals.

Figure 3 – dimensions of change and adaptation.



At first glance, the assumption that adaptation to climate change will occur autonomously across Australian society given an appropriate mix of incentives is at least partially consistent with patterns of observed adaptation. However, a critical question for adaptation policy is whether the *kinds* of adaptation that occur autonomously under current policy settings are appropriate from a societal perspective. For example, the primary response to the Victorian fires of 2009 and Queensland floods of 2011 was emergency management and replacement of housing and infrastructure, with little or no consideration of longer term adaptation to reduce losses from any similar events in future.

Most observed adaptation to date has involved incremental adjustments to existing ways of doing things after significant change has occurred. This incremental adaptation is likely to fall well short of the transformational types of adaptation required to anticipate the challenges of a 2°C or 4°C warmer future.

Many communities and industries are maintaining a passive wait-and-see policy to climate change. This means that adaptation often only takes place as a reaction to extreme events such as fires, cyclones and floods, placing a heavy reliance on the Australian and State governments as “insurers of last resort”.

Effective adaptation at one scale may be dependent on facilitating actions at another scale. For example, the suite of options available to households or small business may depend on local government planning regulations, which are themselves dependent on state and federal policies. The context specific nature of adaptation means that appropriate action is likely to depend heavily on *local* understanding of the risks posed by climate change and strategies for managing these. Governments are likely to be limited in their ability to monitor and influence local adaptation outcomes, but may have a role to play in coordinating adaptation across local contexts and scales.

Governments have a more direct role to play in adaptation for goods and services that they already provide due to their public good nature or associated market failures. These include investments in long lived infrastructure, utilities such as electricity and water, as well as environmental assets such as national parks, the Great Barrier Reef and the Murray-Darling Basin.

Significant examples of maladaptation are likely to impose significant efficiency losses on the Australian economy by foregoing opportunities for lower cost adaptation. For example, a mix of relocation and modified building standards could dramatically reduce the loss of housing and infrastructure in future with increasingly frequent and severe flood and bushfire events.

4 Economic analysis of adaptation

Economic analysis of adaptation helps to explain why the adaptation we see happening across Australian society tends to be incremental responses once significant change has already occurred. As we will see below, it also suggests that significant efficiency losses on the Australian economy will result from foregoing the opportunities for flexible and low cost adaptation.

Unlike action that follows change, adaptation that anticipates future change is a form of insurance that can be undertaken by the private sector or governments or both. It involves making small, relatively certain (precautionary) investments to avoid or manage the consequences of uncertain and potentially much larger future costs.

Framing *adaptation that anticipates change* as a precautionary investment similar to insurance helps to explain the option value often associated with adaptation. In financial terms, a formal insurance contract is an example of a *put option*. An insurance contract specifies the right, but not obligation, to sell a damaged asset at a predefined price if uncertain adverse events occur.

However, framing anticipatory adaptation as insurance or a form of precautionary investment does not imply that it can only be implemented through formal insurance markets. As Garnaut noted, local adaptation is implemented by individuals, households and businesses who can weigh the costs and benefits of taken action to pre-empt climate change and decide whether and how much to invest in self insurance. Self insurance can be financial, through setting aside funds to meet future adaptation expenses. Alternatively it can involve a raft of physical actions to manage risk (raising a house on piers), deal proactively with uncertainty (relocate) or build adaptive capacity (diversify income sources).

The McKinsey Marginal Abatement Cost curve is well known and much debated in Australia (Figure 5). It demonstrates an extraordinarily wide suite of technologies and options with different potential and at different costs, but few people seemed to have picked up on the time dimension – some are feasible to be introduced over the next 2 years plus, but the number that could be rolled out within a year or 2 from now is a very much abbreviated sub-set. We believe that if a similar curve for Adaptation options (not abatement) was drawn, it would also show that the suite of adaptation options available in the short term (1-3 years) is much narrower, and generally at much higher cost, than those that can be implemented progressively over decades, which tend to be transformational rather than incremental.

There is a strong *prima facie* case for thinking that anticipatory adaptation is often likely to be economically more efficient than reacting after significant change has occurred. This is because acting in advance of change is likely to increase opportunities for flexible and low cost adaptation, and enable adaptation responses with potentially adverse and irreversible consequences to be avoided.

Australian 2030 carbon abatement cost curve

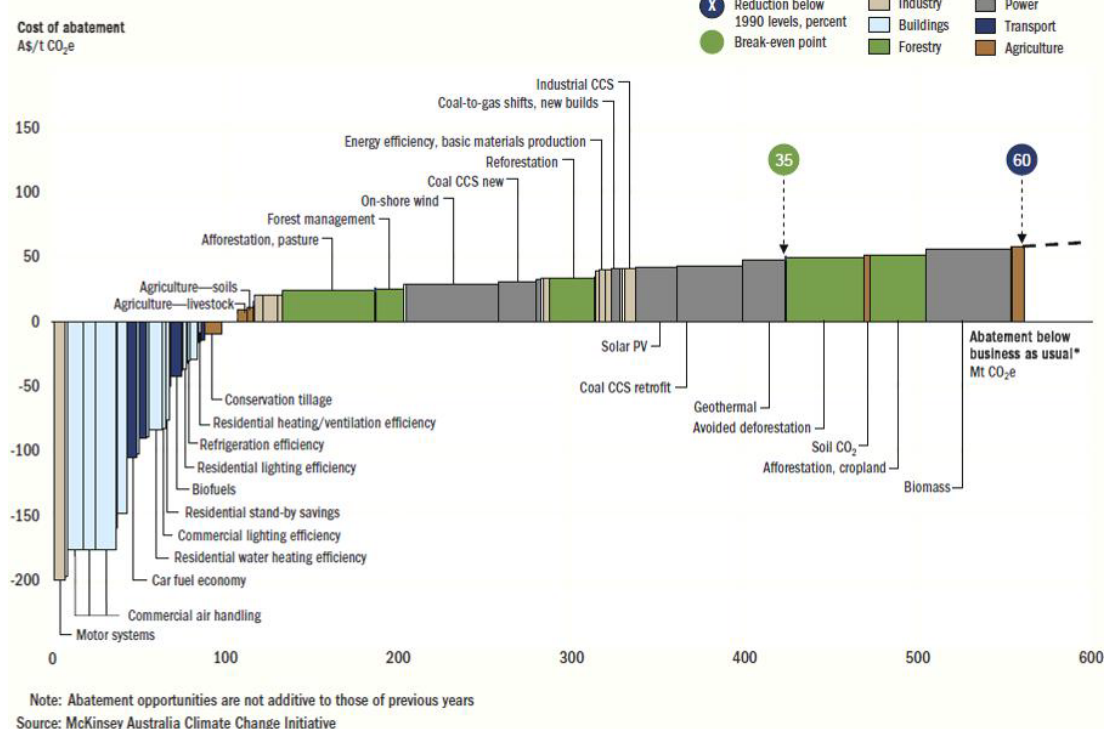


Figure 4 McKinsey Abatement Curve 2030 for Australia

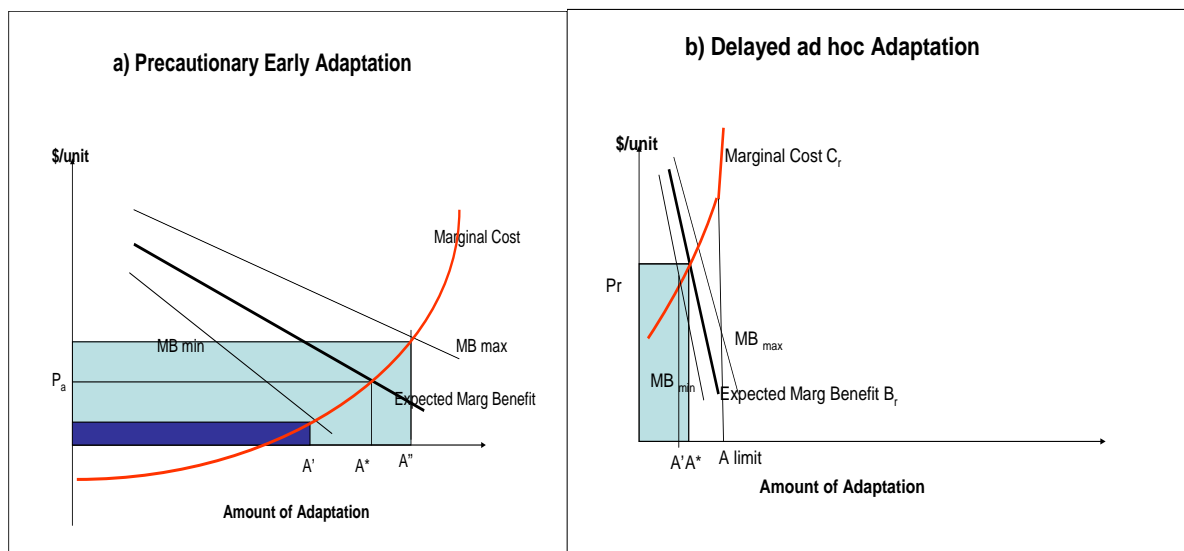
This inter-temporal difference is demonstrated in figures 5 a) and b).

In Fig 5a), the marginal costs of proactively adapting to significant change (C_p) start low, and are likely to include a high proportion of no-regrets options that can be undertaken for other purposes with little or no additional cost (marginal cost starts negative). The costs of adapting to anticipate change rise slowly across a broad set of adaptation options. Adequate time for planning and innovation mean that it is much less likely that adaptation options will be constrained over the relevant range (Marginal cost does not reach a vertical asymptote).

The marginal benefits of adapting to anticipate significant future change start low, but diminish only gradually at higher levels of adaptation (the expected marginal benefits curve has a shallow slope). Marginal benefits start low because there is no pressing need to adapt. Action is taken well in advance of the adverse impacts of climate change. This makes it difficult to evaluate, comparing the immediate and very tangible costs of adaptation against the uncertain and relative intangible future benefits of adapting (the broad range of marginal benefits from min to max reflects the profound uncertainty of the eventual pay-offs from adaptation actions).

In contrast, Fig 5b shows the marginal costs (C_R) of adapting *quickly* (e.g. just before or after significant change has occurred – that timing is immaterial) are likely to start high and rise rapidly within a highly constrained set of adaptation options (C_R asymptotes at A_{limit}). The costs of adapting quickly (at the last minute or after change) start high because many opportunities for low cost, anticipatory adaptation are precluded. Limited time for planning and innovation constrains the overall set of available adaptation options. Those that are available are likely to include a high proportion of crisis responses with unavoidable adverse

Figure 5 – The economics of adaptation.



and sometimes irreversible consequences.

The benefits of adapting after significant change has already occurred start high but diminish rapidly (B_R has a steep slope). Crisis management dictates immediate responses regardless of the cost. Consequently, the benefits of adapting reactively in response to significant change are immediate and certain, but small. The total benefits of adapting after change are small because this type of adaptation contributes little to longer term adaptive capacity (B_R is close to the y axis).

The Pros and Cons of early adaptation action can now be clearly seen: low-hanging fruit, but profound uncertainty about the benefits of acting. However, the consequences of waiting for many years to reduce the uncertainty (gain greater confidence in the expected pay-offs of adaptation) is that the low cost options are no longer available – the only options still available are expensive and deliver little adaptation.

Uncertainty also means that the full value of any single investment in anticipatory adaptation may never be fully realised. Each investment creates the option of a better future outcome – whether or not this benefit is realised depends on the future direction of change, and whether options are exercised. If this option value is accounted for, the total benefits of anticipatory adaptation are likely to be high because it contributes significantly to building longer term adaptive capacity.

The net cost to the economy of relying on late, ad hoc, reactive adaptation (as or after significant change occurs) is the value of foregoing opportunities to anticipate change. In the simple model presented here, this is equal to achieving only A^* at cost P_r in 5b (the value of adapting hurriedly) compared to achieving A^* in 5a at a cost of only P_a (the value of anticipating change). Even if the benefits from early adaptation are at the very bottom of the uncertain range, taking a level of adaptation A' gives far more adaptation coverage than is possible if acting hurriedly, decades later, and at much lower costs (the dark blue rectangle).

This framework provides a possible explanation for why mal-adaptation can occur. If one was thinking ahead a decade or two about urban water supplies, there may be much that could be achieved at relatively low cost, given time, such as water-smart urban design and behavioural changes through demand management, compared with large desalination plants that would be much more expensive. However, if portrayed as a short term decision – that something has to be done within 2-3 years to greatly enhance reliability of urban water supplies – there are few options, all expensive, and desalination plants may look like the best available option in that context. There is also an element of path-dependency – once the large expensive engineering “solution” has been delivered in the crisis, the society is unlikely to go back to thinking about the low-cost transformational changes that might have delivered more adaptation at lower costs – at least until the next crisis.

Another possible example concerns the electricity distribution and transmission systems. If looking ahead 2 to 3 decades, there may be numerous low-cost options for maintaining the reliability of services in the face of climate change over that period. However, over a time horizon of 3-5 years, the expected pay-offs from such investments are probably negligible, so the actions would be readily dismissed as “gold-plating” by price regulators in each period. By the time the need for adaptive actions is unmistakable, many of the low-cost options will have evaporated, leaving only expensive last-minute band-aids that may still fail to maintain normal reliability of supply, even at much higher costs. Again, it is easy to see how path-dependency could mean that the low-cost preventative actions, once overlooked, are not subsequently re-visited.

In sectors adapting only as significant change occurs, it will probably be difficult to refocus adaptation on actions that anticipate future change. This is because adapting reactively once change has occurred *appears* to be efficient within existing ways of doing business. If existing ways of doing things that assume a stationary climate have been established over many years, the benefits of taking more transformational action to anticipate a changing climate will seem intangible. ***For large and uncertain climate impacts***, incremental or transitional efforts to adapt are inefficient, because much more adaptation could have been achieved, by adopting new ways of doing things.

A challenge for economists is to empirically estimate the value of moving beyond incremental adaptation to anticipate significant future climate change. Since continuous change in the external operating environment is likely, a goal of having a process for “adapting well” over time may be more rational than attempting to be “well-adapted” at a particular point in time.

5 Valuing proactive adaptation

The analytical framework above provides a simple but robust foundation for estimating the economic benefits of proactively adapting to anticipatory future change relative to reacting as change occurs. The costs (P_R , P_P) and amounts (A_R , A_P) of adaptation can be estimated using existing research across climate sensitive sectors and regions, and aggregated. These costs and adaptation outcomes can be estimated and compared for incremental, transitional and transformation adaptation options. Increasing sectoral detail can be added to the analysis over time, supported by increasingly sophisticated economic modelling of the costs and likely future amounts of adaptation.

While beyond the scope of this paper, this analytical framework raises the question of how to measure and compare adaptation outcomes (the x axis) - a problem not unique to the

development of *this* analytical framework. Its further development will help to guide the choice of methodologies used by owners and managers of threatened assets, to value and prioritise their adaptation options.

For example, cost-benefit analysis frames adaptation as a choice between well-defined alternatives with reasonably predictable outcomes. It is therefore appropriate for evaluating the benefits of incremental adaptation options. Risk management techniques strive to reduce complex uncertain problems to the conventionally manageable, where risks are known and their probabilities calculated – moving decision-making towards the origin in Figure 3 above. Other methodologies - such as real options analysis – have been developed to guide decision making under uncertainty. These may however be stretched in evaluating transformational adaptation given the profound uncertainties of future change.

6 Market failure & policy options

A number of market failures explain why autonomous adaptation tends to occur reactively after change has occurred, rather than proactively to anticipate future change. One reason is a lack of information and understanding throughout society about climate change and ways of adapting. This is an important market failure, but one that can readily addressed through research and community engagement to embed this research in decision making.

More significant and persistent market failure arises from the related problems of *adverse selection* (Akerhof 1970) and *moral hazard*. These undermine incentives for the private sector to invest in adaptation that anticipates change, regardless of how much is understood about climate change and ways of adapting. Even if climate change and ways of adapting to it were perfectly understood, adverse selection and moral hazard would continue to undermine incentives to adapt in anticipatory, precautionary ways.

This disincentive effect occurs because adaptation is subject to significant principal/agent problems. Investments in public R&D provide governments with a strong scientific case for urgent and significant adaptation throughout society. In seeking to motivate adaptation that anticipates change, the Government (principal) is hampered by an inability to observe efforts made by individuals and businesses to adapt (agents). Without this information, government efforts to facilitate adaptation inevitably favour high risk individuals and businesses, undermining incentives for low risk individuals and businesses to take responsibility for adapting. The result is an over reliance on governments as an insurer of last resort. This may seriously inhibit the appearance or viability of private insurance markets for such risks.

Other market failures that work against anticipatory adaptation include the public good nature of long term investment decisions, regulatory impediments, externalities arising from maladaptation, high transaction costs and concerns for equity across current and future generations.

7 The goal of adaptation policy

A rationale for having an adaptation policy could be to identify policy options which could potentially overcome these market failures and achieve a more appropriate mix of adaptation that anticipates future change, and less maladaptation, than would otherwise be achieved by imperfect markets.

Framing adaptation as a precautionary investment subject to market failure provides a robust analytical basis for selecting from a range of policy options. However, the presence of market failure is a necessary but not sufficient condition for Government intervention. Governments would need to carefully evaluate:

- a) whether policy intervention is likely to improve the proportion of adaptation that anticipates change, compared to what would otherwise be achieved (effectiveness);
- b) whether such a change would enhance efficiency and productivity; and
- c) the benefits and costs of making such interventions.

Policy options for addressing any issue fall into three broad categories across a spectrum from minimal to stronger intervention:

- Information provision, moral suasion, awareness-raising and education;
- Market-based incentives and deterrents; and
- Regulation and prohibitions, accompanied by policing, sanctions and penalties.

In many instances, interventions from all three groups can be applied simultaneously to enhance overall effectiveness, provided that the instruments are well-aligned and not operating at cross-purposes. The appropriate mix of policy instruments is likely to change over time as the problem changes and as previous efforts take effect (for example road safety and anti-smoking).

Across this spectrum, policy options can be selected to address the specific types of market failures affecting adaptation. For each policy option, there is often a wide spectrum of implementation options. For example, the government can regulate to enable the private sector to provide broad-based compulsory insurance (third party road accident insurance), or can provide this insurance more directly through the public sector (Medicare). There are many insights from how Public Health policy has dealt with adverse selection and moral hazard in Canada (Evans, 1985) and Australia, that might be applicable to dealing with these significant market failures retarding climate change adaptation.

Many policy instruments required to address market failures surrounding adaptation are in the hands of state and territory governments. In some cases coordinated action between the Commonwealth and states would be necessary to establish a mix of incentives that would facilitate adaptation in areas critical to achieving national goals. States will be responsible for managing the impacts of climate change on their own activities and assets and the Commonwealth might need to guard against cost-shifting in any negotiations about a national adaptation agenda.

8 Conclusions

This paper has presented a simple conceptual model of the economics of decision-making about whether, when and how companies, local governments and households adapt to the prospect of significant climate changes, in the face of profound uncertainties. The argument that there are significant potential net benefits from anticipatory adaptation, compared to delayed, ad hoc, reactive adaptation or non-adaptation, rests on preliminary evidence of significant cost-savings, particularly for long-term investments requiring transformational (rather than incremental) changes, notwithstanding the profound uncertainty re the pay-offs. Collection and analysis of data to test this proposition is now under way.

Significant market failures are inhibiting spontaneous adaptation. Among the six market failures identified, the two most significant and enduring appear to be adverse selection and moral hazard. These appear to bear many similarities to health economics, and some of the lessons from that area may be helpful in framing policy responses in the Adaptation area.

A potential role of Adaptation Policy of Australian governments might be to address the identified market failures using a coordinated suite of policy instruments designed specifically to address these (subject to the usual test that the intervention generates net benefits compared to the *status quo*).

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