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ADAPTATION TO CLIMATE CHANGE UNDER UNCERTAINTY

It is likely that the Inquiry will receive submissions nominating various specific barriers to adaptation. The purpose of this submission is to focus on the broader picture of the importance of uncertainty to adaptation policy formulation, including its efficient implementation.

Taking a degree of licence, one might characterise a conventional Productivity Commission inquiry as examining an economic shock or policy change in terms of a specific sector or market where the effects are reasonably well known, or at least readily identifiable. It is increasingly recognised, however, that potential climate change, and adaptation to it, represents a complex analytical problem. In particular, the economic shock that climate change represents is likely to be more pervasive in nature, directly affecting all sectors of the economy, albeit in different and unrelated ways. For example, higher temperatures may see crops failing in agriculture, but a higher demand for air conditioners in the residential and services sectors.

Most importantly, the hallmark of climate change is uncertainty. Although much techno-scientific effort to date has been directed to identifying specific effects of future climate change with greater precision, there is now a growing realisation that uncertainty in our knowledge will be a key issue. The summary for policy makers of the IPCC (2011) special report on managing the risks of extreme events and disasters seems to foreshadow this. Even if the primary future effects of climate change could be identified with some degree of probabilistic confidence, far less confidence can be placed in our knowledge of the epiphenomenal effects, or their various permutations and combinations.

Knightian uncertainty and the Rumsfeldian matrix

It has been common for economists to distinguish risk and uncertainty along the lines expressed by Knight (2009, original 1921, p. 9):

> 'It will appear that a measurable uncertainty, or "risk" proper, as we shall use the term, is so far different from an unmeasurable one that it is not in effect an uncertainty at all. We shall accordingly restrict the term "uncertainty" to cases of the non-quantitative type.'

Knight (2009, original 1921, p. 121) elaborates on his definition as follows:

> 'The practical difference between the two categories, risk and uncertainty, is that in the former the distribution of the outcome in a group of instances is known (either through calculation a priori or from statistics of past experience), while in the case of uncertainty this is not true, the reason being in general that it is impossible to form a group of instances, because the situation dealt with is in a high degree unique.'

Clearly, Knight is concerned with cases where at least the event in question can be identified, even if its probability of occurrence cannot always be estimated. In this sense, his formulation of uncertainty

is incomplete, because he does not include instances where even the event itself is unknown, not merely unpredictable.

'Unknown unknowns' – events that can neither be foretold in character, nor predicted in probability of occurrence – were a term of art in military circles well before 2002 when U.S. Defense Secretary Donald Rumsfeld famously occasioned considerable, albeit misplaced, mirth in the media with his use of the term in the context of the war in Iraq. Such cases can by definition become apparent only after the fact, once they have occurred and their nature revealed to the world at large. They represent total uncertainty or 'ignorance'.

Figure 1 seeks to integrate Knightian definitions with the 'Rumsfeldian' approach. It borrows Knight's distinction between knowledge or measurability of probability and lack of it: shown in the columns. The events to which the probabilities refer are shown in the rows as being either known in character, or not. In this case, the events refer to future effects of climate change. Similar tables have been presented by others (e.g. Bammer et al 2008, p. 293) but from different perspectives. The categorisation of risk and uncertainty in Figure 1 is only illustrative and should not be taken to represent a definitive taxonomy[1].

Figure 1 Known and unknown aspects of climate change

	known probability	**unknown probability**
known event or consequence	(I) 'known knowns' (e.g. increased local temperatures for longer periods will affect crop cycles)	(II) 'known unknowns' (e.g. rising ocean temperatures may increase the intensity of cyclones but the frequency of occurrence is not known)
unknown event or consequence	(III) 'unknown knowns' (e.g an indigenous person knows of a rare pest that will thrive in a warmer climate but has not told the responsible authorities about it)	(IV) 'unknown unknowns' (ex post only: e.g. corroded sewer pipes due to reduced water flow in adaptation to drought)

[1] In assessing 'medical ignorance', Kerwin (1993), for example, distinguishes 6 categories of uncertainty, including taboos (things that people are not supposed to know) and denial (things that are suppressed because they are too painful to know).

Uncertainty and barriers to efficient adaptation

The lens of uncertainty allows us to identify barriers to adaptation in a more systematic manner than merely focusing on a deterministic approach based on currently identifiable effects of climate change.

'Known knowns' (quadrant I)

Quadrant I ('known knowns') corresponds approximately to Knight's conceptualisation of 'risk' in that both the event and its probability of occurrence are known, or at least discoverable. An example might be the effect on crop cycles of higher minimum or maximum temperatures (e.g. Franks et al, 2007). In the case of climate change, private individuals can be assumed to have sufficient knowledge to adapt to 'known knowns', provided that governments and the media disseminate information normally. The identification of barriers (e.g. regulatory constraints) should also be relatively straightforward in such situations, and hence amenable to removal by the responsible jurisdictions.

Efficient adaptation by the public sector to 'known knowns', however, is likely to be subject to potentially significant capacity barriers. Where government adaptation measures are contemplated, socially efficient action should be subjected to social cost-benefit analysis. But knowledge of economic appraisal methodologies among public servants is not pervasive; representing an important barrier to the efficient implementation of adaptation measures. Where governments consider adaptation measures in isolation – that is, in isolation from other potential projects like hospitals and schools – there is a further risk of so-called 'stovepiping' that can result in socially sub-optimal outcomes.

A further risk of socially sub-optimal outcomes lies in the popular use[2] of 'damage costs avoided' as a measure of economic benefit. At best, damage costs avoided are a very poor proxy for the conceptually correct measure of 'willingness to pay' for adaptation measures, or the converse of 'willingness to accept' any negative aspects associated with climate change. One reason for the use of this measure is undoubtedly the lack of credible estimates of 'willingness to pay' estimates; a significant barrier to efficient adaptation. There is an arguable case for government to fund a series of studies – preferably in the form of stated preference using Choice Modelling – to determine willingness to pay to ameliorate the effects of cyclones, floods, bushfires, etc, in different geographical regions of Australia. A national database along the lines of the Canadian EVRI[3] would be useful for evaluating mitigation works to limit the effect of 'normal' extreme events, as well as those attributable to climate change.

A significant risk of maladaptation, or risk of inefficient adaptation, lies in the increasing use of techniques such as Multi-Criteria Analysis. Its continued use in government policy formulation merits serious and critical review. Dobes & Bennett (2009) highlight the highly arbitrary and mathematically flawed nature of the technique.

'Known unknowns' (quadrant II)

'Known unknowns' can be typified as matters whose natures are known, but their probability of occurrence is not; a close approximation to Knightian uncertainty. The example given in Figure 1 is that of rising sea temperatures resulting in increased frequency or intensity of cyclones but without specific knowledge about the extent of the expected changes.

[2] Unfortunately often funded by the various Australian governments, including through the agency of the National Climate Change Adaptation Research Framework.

[3] Environmental Valuation Reference Inventory that is maintained by Canada and partially funded by the Australian Government <http://www.environment.nsw.gov.au/publications/evri.htm>

Projects involving cases of 'known unknowns' can be evaluated within a social cost-benefit framework using 'real options' (see for example, Dixit & Pindyck 1994; Copeland & Antikarov 2001; Trigeorgis 1996; etc.) to augment net present values by taking into account the value of strategic flexibility. Examples of the application of the real options approach to adaptation to climate change can be found in Dobes (2008), Howes and Dobes (2011), Linquiti & Vonortas (in press) and Dobes (2012, in press).

Individuals often use real options intuitively to maintain flexibility of action in the face of uncertainty. For example, a young couple buying a residence will often be uncertain whether they will continue to live there if they change occupations, whether they will have a large family or whether the residence might also be used for business purposes. In such circumstances, a 'real option' may be to purchase a smaller residence, but with sufficient land for future extensions if they prove warranted.

Government funding appropriations, on the other hand, are geared towards immediate decisions on projects, with performance often measured in terms of expenditure in line with a predetermined schedule. The system implicitly assumes certainty about the future. The lack of an approach to 'budgeting under uncertainty' in conventional public sector fiscal arrangements thus represent an administrative barrier to efficient adaptation. Adaptation projects that may be found to be socially worthwhile once the option value is included in the net present value calculation may not survive scrutiny, resulting in the loss of a potential benefit, a case of a 'regret'.

Overcoming the administrative barrier of current budgeting approaches would require not only a review of fiscal practices, but also a change in mindset among public servants and politicians. A real options approach requires a degree of lateral thinking and intensive consultation with stakeholders to ensure that all possible options – including interim solutions – have been considered before policy is formulated for consideration by governments. Real options are not merely an analytical tool – they also involve a broader approach to problems than deterministic or mechanistic responses. To the extent that cultural change within government can be instituted, it may well represent a 'no regrets' measure because it would improve general decision-making processes.

'Unknown knowns' (quadrant III)

A case not specified by US Defense Secretary Rumsfeld in his categorisation of uncertainty was that of 'unknown knowns'. This category is more difficult to conceptualise, but is sometimes taken to mean 'conscious ignorance': Bammer et al (2008, p. 293) give the example of riding a bicycle, an act that is harder to accomplish 'when thinking about the actions involved and their necessary sequence'. However, Taleb's (2007) example of the black swan seems more pertinent: even though Europeans, in their 'ignorance' were unaware of the existence of black swans, the fact was known to the inhabitants of Australia, and, probably, Asian traders who visited the shores of the continent. Smithson (2008, pp. 19, 24) gives the example of the Wollemi Pine: while the general public is unaware of the location of the remnant grove, it is known to a small number of officials.

As with most categorisations, conceptual and philosophical caveats abound. For example, the perspective or 'standing' is critical to the black swan example. To humanity as a whole, the black swan is more accurately presented as a 'known known', but to Europeans alone it was more of an 'unknown unknown'. Nevertheless this apparent problem provides an important clue to transforming 'unknown knowns' into 'known knowns' and 'known unknowns' in the context of climate change.

Left to officials alone, there is a considerable risk that adaptation measures will be limited to the relatively narrow professional concerns of those officials (Dobes 2009). For example, council engineers are likely to focus on ensuring that roads are 'climate-proofed' to ensure that they are

accessible throughout the year for 'productive' purposes such as access to employment. Where this occurs, consumers' other interests are likely to be given lower priority in determining adaptation measures. Golf courses may well be neglected, even if local residents have a stronger preference to play golf 365 days a year than to travel by road to shops or to work. A socially better outcome might well be to allow intermittent flooding of the road to the shops and work, but more certain access to the golf course. Again, a barrier to efficient adaptation is research into relative preferences (in the form of 'willingness to pay') of consumers, rather than reliance on officials' interests alone.

A further potential barrier to socially efficient adaptation is lack of adequate consultation with all stakeholders. The wider the consultation, the more likely that a solution is known to someone (even if unknown to most people) and can be implemented. Alternatively, someone may suggest a hitherto unconsidered inexpensive interim solution or 'real option'. Genuinely detailed, extensive and open-minded consultation with the public would be required on the part of responsible officials to surmount the 'unknown' component of 'uknown knowns'.

'Unknown unknowns' (quadrant IV)

By definition, the category of 'unknown unknowns' (quadrant IV) represents total ex ante ignorance, being revealed only after an event has occurred. For practical purposes, the 'unknown unknowns' category is taken to mean events that would not normally be actively perceived, even by those who might have been expected to know. The Knightian definition of uncertainty does not encompass this perspective of total uncertainty because neither the event, nor its probability of occurrence is known.

Melbourne's sewers were designed with specific gradients to operate at a specific flow rate. Although the design engineers may have been aware of some risk at the time, there does not seem to have been any general anticipation of the possibility that water saving campaigns due to a prolonged drought or climate change would have the unintended consequence of reducing flow rates below minimal 'self-cleaning' transmission velocities. This aspect is probably most appropriately categorised as an 'unknown known' because design engineers would have been aware of a potential problem if flow rates were reduced, although most people would not.

However, an apparently entirely unforeseen outcome of greater deposition of biological matter in sewer pipes has been an 'increased … risk of sewer corrosion [from hydrogen sulphide gas build-up] and odours due to more concentrated and warmer sewage' (Melbourne Water, 2011). Although the possibility of greater deposition may well have been appreciated by design engineers, it is less likely that they would also have considered the further possibility of corrosion due to the production of hydrogen sulphide gas due to more concentrated and warmer sewage. This outcome of unexpected corrosion could arguably be classified as an 'unknown unknown'.

By definition, there is no ready means of analysing or appraising specific measures that can be used to adapt to 'unknown unknowns'. Ignoring problems such as expense and moral hazard, one adaptive response might be for governments to adopt the role of 'insurer of last resort' and cover the cost of all extreme 'unknown unknown' events. However, a general lesson that can be drawn from the 'real options' approach is that flexibility is valuable in the face of uncertainty. Applied to a situation of 'unknown unknowns', it is at least arguable that adaptation can be achieved more efficiently in a socio-economic setting that is more flexible.

In particular, there are two areas where greater socio-economic flexibility would be merited:

1. Extensive use of the term 'governance' has tended to devalue and diffuse its meaning. However, it is useful in the climate change context for denoting the coherence of policy formulation and distribution of jurisdictional responsibilities. Duplication or gaps in roles

between different levels of government are likely to arise, given the uncertainty that will accompany climate change. This is especially true of the 'unknown unknowns' where entirely unexpected, unique situations may arise that require either particularly close coordination between different agencies, or the assumption of responsibility by one of them in the absence of clearly defined legislative or political power.

One means of solving the issue is to establish a new coordinating agency with broad powers and ultimate responsibililty for all climate change issues. However, an additional administrative layer is not guaranteed to provide the most efficient solution.

Where existing emergency services can deal satisfactorily with unexpected hazards such as fires and floods, it may best to retain their current responsibilities whether an event is due to climate change or not. The same is probably true for non-emergency services that are best able to incorporate ('mainstream') any additional considerations that may be required to address climate change. However, it may be worthwhile reviewing current institutional arrangements with regard to the principle of subsidiarity: with responsibility for action delegated to levels where it can be most efficiently implemented.

2. A comprehensive program of microeconomic reform would probably go a long way to increasing the flexibility of economic activity in adapting to climate change. Freer labour markets (including freer immigration policies), removal of 'exceptional circumstances' subsidies for farmers in perennially drought-affected areas, further deregulation of sectors such as trade, education, health services, etc, would all contribute to smoother structural adjustment in response to any shocks due to climate change. If climate change results in proportionately more 'unknown unknown' effects than 'known knowns', comprehensive reform may be more effective than addressing only the barriers to 'known knowns'.

   There is a risk that limited, partial microeconomic reform will have unintended distortionary consequences along the lines of Lipsey & Lancaster's (1956-1957) Theory of the Second Best. This is potentially a problem where governments seek only to address barriers to adaptation in areas characterised by 'known knowns' because they are readily identifiable.

Despite the political difficulties that they would inevitably entail, comprehensive microeconomic reform and a review of institutional arrangements represent 'no regrets' measures because they would help promote economic growth. Although growth in itself is not guaranteed to assist adaptation to climate change, it would make more resources available to the community to implement adaptation measures.

Some reflective conclusions

Understandably, there appears to be considerable reluctance to consider climate change through the lens of uncertainty. Techno-scientific specialists in particular prefer to stick to deterministic 'risk management' approaches, despite the fact that they are predicated on being able to both identify and quantify the risk involved. The most recent standards for risk management (Standards Australia/Standards New Zealand 2009) skirt the important issue of uncertainty, and Jones (2008, p. 269) points out that even in 'the discipline of law there is no coherent discourse or even conscious or structured consideration of uncertainty – despite the fact that uncertainty is pervasive'.

Kerwin (1993, p. 172) recounts how Socrates, who was more aware of the extent of his own ignorance than many others, was pronounced by the Oracle at Delphi to be the 'wisest of men'. Acknowledging

uncertainty can provide a fecund basis for developing an improved level of knowledge, because it will eventually spur further inquiry and investigation. Once acknowledged, uncertainty is also more amenable to being managed. It is better to acknowledge and embrace uncertainty ('ignorance'), than to limit ourselves to the bias of the comfort zone that we 'know'.

It is to be hoped that the Productivity Commission will encourage decision-makers to extend their horizons beyond their current comfort zones.

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