VCCCAR Project: Framing Adaptation in the Victorian Context

Options for assessing the cost of climate change for adaptation policy in Victoria

Working Paper 2

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Options for assessing the cost of climate change in Victoria

Summary

Estimating the costs of climate change impacts is the first step in the economic evaluation of adaptation options. Regardless of any future action on climate change mitigation, impacts of climate change in Victoria are already being felt and are likely to intensify in the future. Some effects of climate change could be positive, for example potential increases in agricultural production or reduced human deaths from extreme cold in some regions; but many impacts are likely to be negative, particularly with the projected increase in intensity and frequency of extreme events.

From a public policy perspective there is a demand for an economic analysis of the costs and benefits of climate change impacts that can then be compared with the potential costs of adaptation. These are important for assessing potential risks and making the case for government intervention. However assessing the economic impacts of climate change is challenging and resource intensive and there are a variety of potential approaches that can be used to make these assessments.

It is important to define the objectives for economic analysis and ensure that a) the methodology matches these objectives; and b) the strengths and limitations of the methodology are clearly articulated to end users. In response, this report outlines the main methodologies available for costing climate change impacts with an accompanying analysis of their respective strengths, weaknesses and applicability.

Three broad approaches are generally used to assess the impacts of climate related events:

(a) general equilibrium analysis;
(b) partial equilibrium analysis; and
(c) integrated assessments.

General equilibrium analysis provides a top down approach to economy-wide impacts using computer models based on multiple–sectors of the economy. It considers the impacts and interactions arising from the ‘shocks’ or economic shifts associated with climate-related events between two given points in time and shows how resources may be reallocated due to the impacts of climate change. It is useful when complex flow-on or indirect impacts to an economy need to be assessed, and can also provide insights when multiple markets or sectors need to be analysed together.

Partial equilibrium analysis has the benefit of utilising various and flexible valuation methodologies that can be applied to a variety of impacts, sectors or markets. The disaggregated, bottom-up nature of partial equilibrium analysis does not require overly complex economic models, and is also well suited to exploring the impacts of extreme events; increased frequency and severity of extreme events are a key climate change adaptation concern particularly in the short-medium term.

Integrated assessments capture the strengths of both forms of equilibrium analysis by including analysis of specific sectoral circumstances as well as the flow-on and feedback effects within the economy as a whole. Socio-economic projections and qualitative decision-support tools can also be incorporated. However, they are likely to be more resource intensive.

Key issues worthy of note that are associated with the economic assessment of climate change impacts include: 1) the valuation of impacts on intangibles (such as the environment or amenity values); 2) the selection of an appropriate discount rate; 3) how to incorporate uncertainty, 4) the analysis of low probability though high impact events; and 5) the distributional impacts between different parts of the community. These challenges highlight the importance of transparency regarding assumptions in the way these issues are treated, the sensitivity of results to these assumptions, and the combining of quantitative and qualitative data.

Introduction

Regardless of any future action on climate change mitigation, the impacts of climate change are already being felt in Victoria and these are likely to intensity in the future (DPC, 2009; Garnaut, 2008b, 2011). The biophysical impacts of future climate change in Victoria are expected to include increased average annual temperatures and more hot days, reduced precipitation and drier conditions, changes in hydrological systems and water availability, and more extreme events including floods, bushfires, storms[1]. Over the longer term, climate change is likely to have profound socio-economic implications for Victoria and this report examines the costing of impacts of climate change to inform adaptation decision-making.

In 2010 The Victorian Parliament passed the Climate Change Act recognising that human activity is causing climate change, that climate change is a common concern of humankind and responding to climate change is a responsibility shared by all levels of government, industry, communities and the people of Victoria. Section 14.2 (a) of the Act requires a person making a decision or taking an action resulting from Victorian legislation to consider the potential impacts of climate change relevant to that decision or action. Under the act the relevant minister must prepare a Climate Change Adaptation Plan that sets out (a) an outline and risk assessment of the potential impacts of climate change on various regions of Victoria specified in the plan; and (b) a statement of the Government of Victoria's state-wide priorities and strategic responses for adaptation to the potential impacts of climate change.

Consequently in Victoria, as well as nationally and globally, there is a demand for economic analysis of the costs and benefits of climate change and adaptation initiatives to evaluate the costs and benefits of action today against those in the future and to guide government investment decisions in responding to climate change (Jotzo, 2010; ECA, 2009; Handmer, 2003). An economic impact assessment should ideally value all costs and benefits to society, including social and environmental costs and benefits, however as discussed below assigning monetary value to these impacts is a key challenge.

Adaptation involves complex decisions based on multidisciplinary analysis. In practise decisions regarding how and when multiple groups in society will adapt to current or expected changes due to climate change are made with varied and dynamic priorities, influences and decision-making frameworks (Fuenfgeld and McEvoy, working paper 1). Neoclassical economics provides one such decision-making approach in the form of cost-benefit analysis (CBA), which, in the context of climate change policy, compares the expected costs and benefits of climate change to the expected costs and benefits of adaptation. While the frameworks outlined here relate to costing the impacts of climate change for input into CBA and related decision-support tools, this report is not advocating that these frameworks should form the sole basis for adaptation decision-making. This report focuses on assessing the impacts of climate change only, not the wider topic of the economics of mitigation (lowering greenhouse gas emissions), industry or economy-wide adjustment to a carbon price, or the costs of adaptation to climate change.

Important points regarding costing climate change impacts for adaptation decision-making are introduced in the first section, followed by a summary of climate change impact economic analyses undertaken for Victoria. The next section outlines the methodologies available for costing climate change impacts and their strengths and weaknesses. This is followed by a discussion of some critical issues associated with such analyses. Interspersed throughout the report are examples of analyses undertaken internationally. In the final section, the report considers possible directions for economic assessment of climate change impacts in Victoria.

[1] CSIRO (2010), DPC (2009) and Garnaut (2008b) all provide comprehensive coverage of the predicted biophysical impacts of climate change on Victoria.

Costing climate change impacts

Climate change is expected to have a range of socio-economic impacts. Where, when and how much of these impacts will be addressed by adaptation depends on the approach taken by society. Theoretically society can adapt to: "(i) all those impacts that reduce human welfare, or (ii) all those that are economically feasible (i.e. cheaper to adapt to than to be borne), or (iii) all those that are affordable within a given budget constraint" (Parry *et al*, 2009, pg. 12). Theories surrounding economic feasibility and efficiency, such as those underpinning CBA and the methodologies presented in this report, in many cases assume option (ii). However, the reality may be that option (iii) is more likely, complemented by a feasibility / cost-benefit condition. Ultimately, under an economics framework adaptation will only occur when it is economically feasible for it to do so; hence there will be residual damages that will not be adapted to (World Bank, 2010; Parry *et al*, 2009). Economic analysis can assist policy makers in deciding which adaptation initiatives will be cost effective and which are more likely to provide the greatest return for expenditure.

Garnaut (2008 and 2011) proposed a decision making framework for assessing the costs and benefits of mitigation action by dividing the benefits (or reduced costs) of mitigation into four categories. Type 1 benefits those that can be easily measured and modelled; Type 2 are those that are not readily measureable (e.g. the increased costs of new building designs, maintenance or impacts on international tourism); Type 3 is the insurance value of mitigation derived from avoiding potentially catastrophic impacts; and Type 4 are non-market benefits such as environmental amenity or quality of life that are difficult or impossible to measure within current economic frameworks.

The basic principle behind any economic assessment of an adaptation strategy or initiative is to ensure that the expected benefits exceed the costs i.e. that the benefit-cost ratio is above one. The benefits of adaptation include reduced costs of climate change impacts. Hence estimating the economic and social impacts, or the net cost, of climate change is the first step in any economic evaluation of adaptation (World Bank, 2010). However, studies across the world have recognised that estimates of the costs of climate change impacts are often not readily available (ECA, 2009; Metroeconomica Limited, 2004)[2]; this is confirmed by a review of studies on the costs of climate change in Victoria. Globally, there has been more analysis of sectors that will be impacted by climate change mitigation policies than on the cost of impacts or adaptation. If Victorian communities, industries and Government want to utilise economic decision-support tools for adaptation then this gap will need to be filled.

Adaptation will require public expenditure and spending by firms and individuals. Allocation of the responsibility for the costs of climate related events to different levels of government and between the public and private sectors is the subject of continuing debate. While government would prefer to see a greater degree of self reliance and firm or individual responsibility for risk management, in many cases the impacts of large-scale events fall to state or national governments. Under theoretically ideal economic conditions markets would be perfect and economic actors would respond to changing environmental conditions instantaneously and rationally with full information. Under these circumstances public funding for adaptation to climate change would not be required. However markets for many things that society values are imperfect or nonexistent (such as for many environmental services) and there are high investment and transaction costs for changing infrastructure or production methods. Furthermore, adaptation will be required for public goods[3] such as public infrastructure or biodiversity, and for aspects of emergency response. Public policy interventions will therefore be required to ensure optimal adaptation spending (Aaheim & Aasen, 2008).

The two most common methodologies utilised by economists to estimate the cost of climate change impacts are a) partial equilibrium analysis which looks at impacts in one sector or region; and b) general equilibrium analysis which looks at impacts across a whole economy (Nunes and Ding, 2009). These methodologies, discussed in detail below, are not mutually exclusive and both approaches have been applied to assess the costs of climate change in particular studies.

[2] The economic case for disaster risk reduction (with regards extreme events) is better established (Crompton & McAneney, 2008).

[3] A public good is one where adaptation initiatives are costly to the individual who implements them but benefit all users, resulting in inadequate incentives for individual investment.

Integrated assessments involve the utilisation of these equilibrium analyses and other qualitative methodologies to explore the economic impacts of climate change.

Transparency about the quality of data and estimates, and inherent uncertainties is needed if analysis is to be useful for policy-makers. The selection of methodology and data can have a significant impact on estimates of current day disaster impacts in Victoria, highlighting the importance of transparency (Keating, 2011). Furthermore, the potential direct and indirect impacts of different types of low probability-high impact climate related events should not be discounted, nor their respective probabilities, because some impacts, due to the complex interactions of social, economic and environmental systems into the future, will remain outside the realm of prediction (Weitzman, 2009; AGO, 2004).

What we know about the costs of climate change impacts in Victoria

Jones and Webb (2008) undertook a assessment of Victoria, evaluating vulnerability to climate change impacts in nine sectors and Victoria's eleven regions (defined by Australian Bureau of Statistics statistical divisions). "Vulnerability is framed as potential future impacts contrasted with our understanding of vulnerability to current impacts" (Jones and Webb, 2008, pg. 5). Vulnerability was assessed along the categories of 'economic', 'social' and 'environmental' impacts. The authors classified impacts as low, moderate or high for each sector and region – hence it was a qualitative assessment. This 'triple bottom line' approach is in fact another way of expressing the point emphasised later in this report, that a full analysis must consider all impacts that are valued by society.

Jones and Webb (2008) found that potential economic impacts (as defined by the authors) were unevenly distributed across the state and between sectors, having most impact in the water, manufacturing and primary production sectors in certain geographical areas. Social impacts were found to be high for water and primary production, and moderate for energy, natural resources and biodiversity, and health. Environmental impacts were found to be high for water, natural resources and biodiversity, and moderate for primary production. A low rating does not mean that impacts will not be felt, simply that they will be small relative to the size of the sector[4]. Potential vulnerabilities were determined for two time periods - 2030 and 2070. Findings suggest that in the shorter term (2030) most issues will be related to increased frequency and severity of extreme events including drought, fire and flooding. When looking out to 2070 systems will become increasingly stressed and adaptation to a changing climate will become much more difficult. The authors identified the potential for significant flow-on effects throughout some regional economies and value-chains, though stressed the fact that their vulnerability analysis looked at sectors individually and as such these cascading effects were not covered and more research would be needed to better understand this complexity.

The Victorian Climate Change Green Paper (DPC, 2009) cites water, ecosystems, the built environment, health and wellbeing, and emergency services as being adaptation priorities. These priorities are consistent with the Jones and Webb (2008) analysis, the Government *Our Water Our Future* plan, and other Government spheres of influence and priority. The discussion of adaptation priorities does not include quantitative analysis of the expected costs of impacts.

CSIRO (2007) estimated the financial impacts[5] (not including consequential losses) of climate change on Victorian infrastructure. This analysis estimated the impact on infrastructure services, social amenity, governance and the cost of maintenance, repair and replacement. The report found that the water sector is at very high risk, followed in order of priority by the buildings sector, transport sector, power sector and at least risk the telecommunications sector. Consumer price increases are expected for water, electricity and gas.

Keating (2011) summarised a variety of estimates associated with the cost of current day extreme events in Victoria. This analysis highlighted the difficulties associated with generating cost

[4] Since the analysis was qualitative only, the actual size of the impacts was not established.

[5] Note this is not a full economic analysis.

estimates of current day extremes, the uncertainties of which will only increase with projections under climate change.

Other studies have looked at various aspects of climate change impact in different parts of Victoria. For example, Brooke & Kinrade (2006) qualitatively assessed the impact of climate change on different sectors in Western Port, including water resources, agriculture, tourism and biodiversity.

Overall, while there is scattered, qualitative information on the impacts of climate change for different sectors in Victoria, there has been no systematic evaluation of economic impacts.

Frameworks for assessing the cost of climate change

A comprehensive assessment of the costs of climate change impacts is needed if decision-makers wish to utilise economic decision-support tools to assess adaptation options. Information about the costs of climate change impacts can inform adaptation decision-making on many levels and sectors, not only for government. For example industry or community groups may utilise information on the cost and location of expected climate change impacts, reflecting the fact that adaptation is very much local and context-specific. Once the costs of climate change impacts are estimated, they can be compared to the cost of adaptation initiatives to determine which adaptation initiatives would be most cost effective, and where. Economic analysis of this kind can provide useful input into the decision-making process. Notably none of the analyses outlined above provide a thorough economic impact assessment of climate change for anywhere in Victoria.

Welfare economics is the approach underpinning economic evaluation of the costs of climate change. Welfare economics aims to convert all costs and benefits into a standard unit (currency) so that they may be weighed against each other, and trade-offs can be made. "All costs and benefits" should theoretically include everything that is valued by people, including things that are not traded in a market place such as social and environmental impacts. Value is determined by individual preferences which can be defined as the willingness to accept (WTA) or willingness to pay (WTP) (Farber *et al*, 2002). AGO (2004, pg. 5) defines these as:

- **Willingness to accept (WTA)** - the minimum payment that the owner of a resource is willing to accept for its use.
- **Willingness to pay (WTP)** - the maximum amount a consumer is prepared to pay for using the resource.

The AGO report (2004, pg. 5) goes on to say that "if applied in the context of costing the impacts of climate change, WTP measures the maximum people would be willing to pay to avoid a particular impact (by adopting, for example, adaptation or mitigation strategies), while WTA measures the minimum people would be prepared to accept (as compensation) for living with the impact." Impact assessments look at different types of costs and benefits – economic (opportunity) cost, financial cost, social cost and private cost[6]. Partial equilibrium analysis and general equilibrium analysis are the two broad methodologies that utilise welfare economics to estimate the economic impacts of climate change, these are discussed below and summarised in Table 1. Fundamental issues associated with all economic impact assessments are discussed below.

To estimate the costs of climate change a baseline scenario, that is projections of a future without climate change, is often used. A static baseline creates projections under a future where all other environmental and socio-economic conditions remain as they are today (Tol, 2002b; AGO, 2004). It should be noted that most analyses, regardless of their type, take a static approach. They look at the impacts of a discreet change in climatic conditions on the current system. While this type of analysis provides a useful starting point it is important to remember that the climate as well as economic and other societal conditions will continue to change and dynamically interact (Hallegatte *et al*, 2008; Tol, 2002b). A dynamic baseline attempts to account for projected changes in non-climate change conditions. While the use of a dynamic baseline increases the uncertainty inherent

[6] For a fuller discussion and further references on these economic principles see AGO (2004) and Metroeconomica Limited (2004).

in the model (discussed below), uncertainty is increased no more so than in any other economic forecasting (World Bank, 2010; AGO, 2004).[7]

Partial equilibrium analysis

Partial equilibrium analyses estimate the costs of climate change impacts for a single market or sector (Nunes and Ding, 2009), and are also utilised for analyses of a location or region. They are called 'partial equilibrium' because they look at the impacts of climate change in one sector or region only while holding all other things constant; hence they do not consider how climate change impacts from other sectors or regions will impact the sector or region under consideration, or how changes in the subject sector or region will impact the wider economy. These analyses utilise disaggregated data and are hence sometimes referred to as 'bottom-up' (see for example AGO, 2004).

Partial equilibrium analysis estimates impact costs by utilising economic valuation techniques that can be categorised as either 'directly observed market behaviour' or 'hypothetical market behaviour'. Direct observation methods value goods and services that are traded in the market place; hypothetical market methods are used to value intangibles - things for which there is no observable market. From AGO (2004, pg. ES.3):

- **Direct observation** methods use the prices for goods and services that are traded in the market to estimate producer and consumer surplus and thereby directly or indirectly infer cost or value relating to the affected good or service. These can, in turn, be split into two further categories:
  - 'direct markets', which will cost climate change impacts using the market price of the affected good or service which has been obtained in a conventional market; and
  - 'indirect markets' will cost climate change impacts by observing behaviour in surrogate markets for an affected good or service.
- **Hypothetical market** methods are generally used when value is not directly observable in the market, as is the case with 'non-use' values.

For a delineation of the specific methods utilised for these types of analyses see AGO (2004, sections 3.2.2 – 3.2.7) and Metroeconomica Limited (2004).

Partial equilibrium analysis has the benefit of utilising various and flexible valuation methodologies that can be applied to a variety of impacts, sectors or markets. The disaggregated, bottom-up nature of partial equilibrium analysis does not require complex economic models, and is also well suited to exploring the impacts of extreme events; increased frequency and severity of extreme events are a key climate change adaptation concern particularly in the short-medium term.

A key limitation of partial equilibrium analysis when used in isolation is that it assumes that the impacts of the change under examination will not be significant enough to affect prices through changes in output or demand. When we consider that climate change is likely to have far reaching impacts across many sectors and regions, this limitation of partial equilibrium analysis is exacerbated. However, this type of analysis is still considered useful because it highlights the type and magnitude of impact in the sector or region under consideration. Projections on how climate change impacts are likely to impact price requires information about the demand and supply functions for the market, and price elasticity of demand. However, AGO (2004) argues that this analysis, if required, can be done by the use of a simple model.

Partial equilibrium analysis is best suited for local or regional scale climate change impact assessment in the short-medium term. It is locally contextualised because it uses actual observed data and looks at impacts by specific market or sector. Furthermore, it does not require complex economic models and this may appeal to some decision-makers. However, partial equilibrium analysis captures only impacts on a single market or sector; it assumes that impacts in that sector will not have significant flow-on effects to the rest of the economy. Therefore, partial equilibrium analysis alone will not provide an accurate picture of climate change impacts within a region, even if numerous sectors are analysed (Hallegatte *et al*, 2008).

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[7] For a fuller discussion and further references on these economic principles see AGO (2004) and Metroeconomica Limited (2004).

Examples of partial equilibrium analysis methodologies and studies

Costing the Impacts of Climate Change in the UK: Implementation Guidelines Final Report

Metroeconomica Limited's (2004) report on costing the impacts of climate change to the UK provides a detailed outline of a methodology utilising standard economic techniques for costing climate change impacts. It outlines a method for identifying and measuring impacts in physical units and converting these to monetary values. Market-based goods and services (tangibles) are valued using a 'change in productivity' approach, while impacts on asset stocks are valued using cost-based methods such as 'replacement cost'. The methodology also discusses the valuation of intangibles through hedonic pricing, travel cost, contingent valuation and benefit transfer.

The Economics of Climate Change Impacts and Policy Benefits at City Scale: A Conceptual Framework

Hallegatte *et al* (2008) describe how global socio-economic and emissions scenarios can be downscaled to a level useful for city level impact assessment. They incorporate dynamic projections of other variables such as urbanisation and economic development. Scenarios produced are then used to estimate the physical and economic impacts of climate change at the local scale. The methodology provides direct losses at the sectoral level (partial equilibrium analysis) but recognises that these estimates are conservative as they do not include likely economy-wide interactive impacts.

Shaping climate-resilient development: A framework for decision-making

ECA (2009) outlines a framework for quantifying a location's "total climate risk" which includes estimates of expected annual loss under current climatic conditions, and projections under potential future socio-economic and climatic conditions. This is done by identifying 'most relevant' hazards and which people and assets are most at risk. The cost of current hazards is evaluated under current conditions, and projections about future conditions are used to scale-up hazard impact estimates. The second part of the framework evaluates adaptation options. The test cases highlighted just how locally specific impacts may be, and as such impact assessments should emphasise local context and not scale-up results from a few specific locations.

General equilibrium analysis

General equilibrium analysis looks at the impacts of climate change on the economy as a whole, capturing the flow-on effect of an impact on one market to the whole economy (Nunes and Ding, 2009; World Bank, 2010). General equilibrium analyses, increasingly in the form of Computable General Equilibrium (CGE) models, are based on a quantitative and aggregated model of the economy. These models consist of a set of parameters that utilise observed economic data and assumptions about the relationships (supply and demand) between them. The model system is then 'shocked' via changes in exogenous variables, and the flow-on impacts throughout the system are observed. The aggregate impacts can be represented as changes in GDP (Gross Domestic Product – the usual measure of national economic performance) or consumption (Jotzo, 2010; AGO, 2004). It is called 'general equilibrium' because the model is designed to capture outcomes throughout the whole dynamic system (Nunes and Ding, 2009). The Garnaut Climate Change Review utilised this type of model when examining the cost of the impacts of climate change on the Australian economy; this was the largest modelling of the Australian economy ever undertaken (Garnaut 2008a & 2008b).

General equilibrium analysis models impacts and interactions over different sectors and regions, and how resources may be reallocated due to climate change. It allows for the modelling of impacts on relative prices, trade, and production and consumption patterns. The long timeframes associated with climate change mean that capturing dynamic interactions over time are fundamental to the analysis (World Bank, 2010). General equilibrium analysis is useful when complex flow-on or indirect impacts to an economy need to be assessed. It can also be used when multiple markets or sectors need to be analysed together.

Modelling of this kind necessitated the use of simplifying assumptions and generalisations regarding model parameters. The empirical evidence for the calibration of parameters is often scarce (Jotzo, 2010) and the task of accurately capturing deeply complex and dynamic interactions within a model is a key challenge (Hallegatte *et al*, 2008). A further limitation of general equilibrium models is that they cannot effectively model the impact of non-price related policies and shocks. Adaptation policies relating to land-use planning or behavioural change for example, are not well accommodated for (AGO, 2004). In relation to increased frequency and severity of extreme events expected due to climate change, general equilibrium analysis struggles to provide policy guidance due to the fact that impacts are dispersed throughout an economy-wide model and as such they can become relatively insignificant.

Traditional general equilibrium analysis often assumes a high degree of substitutability in both production inputs (for example between land, labour and technology) and consumption; this assumption is debated because the reality for many production processes is that the ratio between inputs is more fixed than these models assume. Furthermore these models contain strong assumptions about productivity growth which often outweigh the impacts of climate change (Jotzo, 2010).

In his example relating to food production and prices, Jotzo (2010) highlights serious limitations inherent in the assumptions underpinning general equilibrium analysis: on the production side there is a physical necessity to produce a certain amount of food per person and this constraint is often inadequately captured in general equilibrium analysis. Similarly in relation to food prices, the profound impacts of feedback impacts onto food prices are not well captured, resulting in models that predict only small changes in welfare. This example of food is powerful because it highlights the limitations of a model that is unable to realistically capture the profound impacts food shortages and food price increases will have on a population.

Jotzo (2010) argues that the limitations of general equilibrium modelling are so pervasive that they render quantitative estimates invalid. In particular he argues that doubts about the quality of estimates at the aggregate level are magnified with regard to policy decision-making at the disaggregated level. A study by Bosello *et al* (2009) is used to highlight that “total net climate change damages are less than half a percentage point of GDP at 2050, compared to GDP typically expected to more than treble over the time span. This is in a scenario of a 3 degrees increase in mean temperatures, which now generally regarded to herald unacceptable risks from climate change for humanity” (Jotzo, 2010, pg. 10). While the critique relates specifically to Bosello *et al*'s global study, and as such comparisons with a hypothetical Victorian study are limited, it demonstrates how the assumptions necessary for general equilibrium analysis can have profound and – some may argue – illogical outcomes.

Example of general equilibrium analysis

The Garnaut Climate Change Review

Garnaut (2008a & 2008b) undertook the most extensive modelling of the Australian economy and climate change to evaluate climate change impacts and mitigation options. A CGE model of the Australian economy, coupled with a global modelling framework to assess trade impacts, were utilised. Estimates based on the CGE model of the economic impact of unmitigated climate change for Australia take account of ‘Type 1’ costs only; ‘Type 1’ costs are justifiably measurable market impacts in ‘average’ climatic change scenarios. ‘Type 2’ costs, which include those less easily measured, are added on later via sectoral analysis. The model does not account for more extreme impacts or non-market based valuations such as the impact on biodiversity or health.

Integrated assessment

The relative strengths and weaknesses of partial and general equilibrium analysis, coupled with the key issues outlined below, mean that many studies utilise both forms of analysis to improve the breadth and depth of outputs. The term ‘integrated assessment’ is used for these approaches but is not uniformly defined in the literature; it simply tends to refer to an assessment of climate change costs that includes several elements. Jotzo (2010) refers to an ‘integrated assessment model’ as one that models impacts, potential mitigation paths and adaptation potentials. Bell *et al* (2003) and AGO (2004) describe ‘integrated assessment models’ as ones that include both socio-economic and biophysical modelling. The term is a catch-all for assessments that bring together several analysis types, including scenarios, qualitative and computer modelling both from a bottom-up and national/regional level (see examples below).

Integrated assessment attempts to capture the strengths of both partial and general equilibrium analysis by including analysis of both specific sectoral circumstances, and the flow-on and feedback effects within the economy as a whole (World Bank, 2010). They may also incorporate socio-economic projections, for example relating to population and land use, and how these may interact with climate change impacts (AGO, 2004). Integrated assessments may utilise qualitative decision-support tools in conjunction with economic analysis (Bell *et al*, 2003). An integrated assessment might separately assess the risk and impact of increased frequency and severity of extreme and / or catastrophic events.

Examples of integrated assessments

The Economics of Adaptation to Climate Change

The World Bank (2010) study on the economics of adaptation to climate change utilised both a CGE model to estimate global adaptation costs, and an integrated analysis for several countries using national CGE models and disaggregated sectoral analysis. The baseline for analysis is dynamic in that it describes a scenario without climate change but incorporating projected trends in development and policies.

Climate change impacts in Europe: Final report of the PESETA research project

Ciscar *et al*'s (2009) pan-European study selected five sensitive 'impact categories' (agriculture, river floods, coastal systems, tourism and human health) and utilised climate data and sector-specific economic models to develop impact models. Partial equilibrium analysis was used to analyse the economic impacts of climate change on each sector under current economic conditions (socio-economic development was considered in some sectors). A CGE model then incorporated sectoral results as inputs to analyse indirect economic effects and translate results into welfare and GDP changes. The study acknowledges that its focus on only five sectors means results are clear underestimations of climate change impacts.

Table 1: Summary of assessment methodologies

Analysis name	Analysis scope	Advantages	Disadvantages
Partial Equilibrium Analysis	Impacts on single market/sector, or location, holding all else constant.	-Captures market/sector specific impacts. -Complex modelling not required. -Multiple valuation methods. -Extreme events can be incorporated into the analysis.	-Ignores interactions/flow-on effects with other markets or sectors. -Assumes impacts will not be large enough to impact price through changes in supply and demand.
General Equilibrium Analysis	Models impacts across the whole economy.	-Captures economy-wide interactions and reallocations due to climate change. -Captures impacts on relative prices, trade, production and consumption.	-Complex modelling required. -Extreme events generally handled inadequately. -Uncertain assumptions underpin models. -Difficulty in capturing the impacts of non-price related policies.
Integrated Assessment	May include elements from partial and general equilibrium analysis, as well as other qualitative tools.	-Attempts to capture both sectoral specific impacts as well as economy wide interactions and effects. -May incorporate qualitative decision-making methodologies.	-Suffers from the disadvantages of its components.

Key issues and limitations in economic impact assessment

The issues outlined below – the treatment of intangibles, distribution and equity, discounting, uncertainty and low probability/high impact catastrophes are key issues that arise in the context of assessing the cost of climate change impacts. The way in which analysts handle these key issues can have profound impacts on analysis outcomes, and it is important for end-users to appreciate how these issues have been treated in a given analysis. These issues also highlight broad limitations inherent in CBA (cost-benefit analysis) style analyses.

Intangibles

As stated above, an assessment of the costs of climate change would ideally include all things that are valued by society – including things such as the value of human lives, environmental amenity, ecosystems and the services they provide, cultural heritage and community cohesiveness. The Victorian Government (DPC, 2009) recognises the importance and value of Victoria's natural ecosystems. Unfortunately including the value of intangibles in climate change impact assessments is a significant challenge because it involves attributing a dollar value to them; this is both technically challenging and resource intensive (Barkmann et al, 2008; Boyd and Banzhaf, 2007; Keating, 2011). Experts at the September 2010 VCCCAR workshop acknowledged that this issue is an ongoing challenge. Not only is it technically challenging and resource intensive, valuing intangibles also highlights a deep ideological debate that exists about whether it is a valid exercise to attempt to attach a monetary value to the environment (Farber et al, 2002; Bell et al, 2003), and to human lives.

The 'hypothetical markets' approach to valuing intangible climate change impacts outlined above is the main option available to analysts. Analysts can use techniques such as a) stated preference methods such as contingent valuation, where a carefully structured survey asks respondents their willingness to pay for specified changes in the intangible (Carson *et al*, 2003); and b) hedonic pricing methods where value of a particular environmental attribute can be observed in a proxy markets, for example in variations in residential property value. While these methods are now sophisticated and widely used, their validity remains controversial because data are not directly observed (Barkmann et al, 2008).

A key concern related to valuing the impact of climate change on intangibles, particularly in relation to ecosystem services, is the question of substitutability. Even if impacts on these natural systems can be valued and incorporated into an economic analysis, analyses such as CBA tend to assume that value is substitutable eg., that we can trade ecosystem services for more consumption. There are many instances where human-produced capital is not an adequate substitute for natural capital (Neumayer, 2007; AGO, 2004), and as the availability of natural capital declines, substituting will become increasingly difficult. Costanza *et al* (1997) attempted to attach a value to the world's biosphere and have been heavily criticised for using marginal valuations to aggregate total value (van den Bergh, 2004). These studies are at the global scale, however, the issues are particularly important at the local level where substituting assets may not be possible. .

Despite these concerns, we do know that omitting intangible (non-market) impacts limits the insight provided by all types of analysis. The lack of intangibles may bias the analysis to consideration of tangibles only. The omission of intangibles generally biases cost estimates downwards because the overall impacts of climate change on natural systems is thought to be negative (Nunes and Ding, 2009; Jotzo, 2010). However, it may be the case that many adaptation options pass a cost-benefit criterion even when intangibles are not included; such is the case with many extreme events (Keating, 2011; Crompton and McAneney, 2008).

Even when it is impossible to assign a dollar value to an impact it is essential for that impact to still be included in the analysis discussion. The use of qualitative impact assessments that describe impacts on intangible assets under various scenarios is the main option for dealing with un-costed intangible impacts (Kiker *et al*, 2005; AGO, 2004; Metroeconomica Limited, 2004). This further highlights the fact that economic analysis ought to be one of many inputs into the decision-making process.

Distribution and equity

Aggregate estimates do not take account of the distribution of impacts (Tol, 2002a); this is a concern for climate change analysis because impacts and costs are unlikely to be borne uniformly between sectors, regions, communities or income groups. Fritze (2007) finds that climate change impacts may impact low-income and disadvantaged Victorians disproportionally. Including an exploration of the distribution of impacts and costs therefore needs to be an integral part of any analysis. This can be done via a formal equity weighting for some impacts depending on who they are impacting, or simply a break-down of where impacts and costs will be borne (Tol, 2002a; AGO, 2004).

Formally accounting for equity in an impact assessment via an equity weighting is not a simple task and subject to ideological debate (Kiker *et al*, 2005). The issue of distribution and equity highlights the fact that economic analysis should only be one part of the decision-making process. The use of more qualitative decision-support tools such as multi-criteria decision analysis (Bell *et al*, 2003; Kiker *et al*, 2005) can be utilised in an integrated assessment to inform decision-making.

Discount Rate

Discounting is used in economics to convert future costs (and benefits) into present day values. Discount rates are generally positive because they reflect a preference for consumption today over consumption tomorrow, or the rate of return on capital investment. If a discount rate is zero this indicates that costs in each time period are valued equally; the higher the discount rate, the less future costs are valued (Nordhaus, 2007). Small changes in the discount rate can have enormous impacts on net present value (van den Bergh, 2004; Nordhaus, 2007).

Discounting is used to estimate net present values, which are used to evaluate economic efficiency. In this context a decision is efficient (has a cost-benefit ratio of greater than one) if the expected benefits, in today's dollars (net present value) exceed the expected costs in today's dollars. Within the constraint of discounting economic efficiency may very well be obtained because, for example, the costs of damages to ecosystems are discounted because they occur in the future. Often, ecosystem costs are simply not included in the analysis because of the absence of agreement on their value. However, economic efficiency says nothing about sustainability or equity. Just because something is economically efficient does not mean that it is sustainable (van den Bergh, 2004).

The selection of the discount rate is a contentious issue in climate change policy because it is the primary way in which costs and benefits to future generations are weighted against costs and benefits to the current generation (Farber et al, 2002). Discount rate can be determined in a positive or a normative way (Garnaut 2011). Positive approaches to economic analysis involve observation, description and explanation of economic phenomena, while a normative approach aims to consider values and ethics. A normative approach to determining the discount rate is derived from judgements about how to value the wellbeing of future generations compared to those of today. Reflecting Stern (2007) Garnaut suggested that a normative approach is more appropriate for climate change where issues of equity and sustainability are important.

The higher the discount rate, the less value ascribed to impacts felt by future generations hence the discount rate reflects our treatment of intergenerational equity (Nunes and Ding, 2009). Van den Bergh (2004) argues that since a society, unlike an individual, does not have a finite life the concept of a time preference is not applicable. The fact that climate change impacts may be irreversible is another argument for a lower discount rate than the rate of return on capital (Neumayer, 2007; AGO, 2004). Garnaut (2008 and 2011) argued that the only rationale for valuing the welfare of future generations less than our own in a completely normative sense is if there is a probability of human extinction, which he considered high unlikely (even over a long time-frame) but not zero and therefore a very low rate of 'pure' time preference is applicable (he used one twentieth of one percent). This was the approach used by Stern (2007). Stern's approach has been critiqued by many economists on a range of grounds (see for example Nordhaus (2007) and Tol and Yohe (2006). For example, Nordhaus suggests that a "Rawlsian perspective that societies should maximise the economic well being of the poorest generation" would argue for increased current consumption and a higher discount rate, as would the ethical argument that we should concentrate our efforts on raising the living standards of the world's poorest,However, Garnaut further argued that there was a case for discounting the well-being of future generations because they are likely to be richer than current generations in material terms. Developing the discount rate according to this normative principle is similar to that for redistribution of wealth within a current society. He used the concept of the 'elasticity of utility' to address this issue. This placed the choice of interest rate within two bounds, the lower determined by 'pure' normative rate (where one percent of today's income is the same as one percent of a future, higher income) and a rate where income forgone today results in double that income gained in the future in percentage terms. This put the interest rate at between 1.35 and 2.65 percent. This was also within the range that might be result from a positive approach. For example, the long term inflation-adjusted rate of return of government bonds in Australia and the USA is 2.2 and 2.1 percent respectively.

In their study of the impacts of climate change in five European sectors, Ciscar *et al* (2009) decide to avoid the discounting problem by reporting un-discounted monetary effects.

Experts at the September 2010 workshop suggested that presentation of results under various discount rates (i.e. discount rate sensitivity analysis), within a range based on positive and normative approaches would be useful to policy-makers.

Uncertainty

To varying degrees uncertainty exists for all projections about the future. In relation to climate change impacts there is uncertainty about the biophysical impacts, and uncertainty about how these will translate into socio-economic impacts (World Bank, 2010). The further into the future we predict the more uncertain our assumptions become (World Bank, 2010). Garnaut (2008b) argues that pressures from increasingly speculative assumptions about carbon price and climate change impacts in his models mean that they become useless for analysis beyond the end of the 21st century. As discussed above, the choice of discount rate can have a significant impact on the relevance of impacts into the future.

Relationships between emissions, temperature increases and other physical impacts may result in feedback loops and are probably not as linear as implied by many models. A probabilistic determination of the risk of catastrophic and/or irreversible impacts may not be possible, nor may it be feasible to predict the economic impacts of such events (Jotzo, 2010; AGO, 2004). The common approach of valuing impacts according to an intermediate scenario (see for example Garnaut, 2008a) neglects to account for extreme impacts, which may be driving concern about climate change in the first place (Jotzo, 2010; van den Bergh, 2004).

All economic predictions are based on assumptions about future trends in population, investment, technology and wealth accumulation, just to name a few variables. These assumptions are often based on observations of past behaviour and trends which may not apply in the future (World Bank, 2010). With climate change likely to have profound and far-reaching effects on society, the justifiability of the use of past trends in models becomes increasingly speculative the longer into the future projections are made (Jotzo, 2010; Garnaut, 2008a). However, if this constraint is firmly acknowledged an analysis will still have merit. As pointed out by Tol (2002a), investigating the impact of climate change on the current situation allows for only one parameter (climate) to be varied thereby reducing uncertainty, and results are still usefully indicative of key impact sites and relative vulnerabilities.

Despite inherent uncertainties there are economic tools available for decision-makers working under uncertainty. If there is reasonable knowledge of the probability of an event or circumstance, analysts can incorporate tools such as Expected Monetary Value (EMV), expected utility criterion and expected value risk analysis. In situations where uncertainty is more significant sensitivity analysis, Monte Carlo simulation and interval analysis all add much to an analysis (AGO, 2004).

Sensitivity analysis is in fact essential for any analysis. It can help explore the breadth of uncertainty in estimates. In economic modelling the usual practise is to vary key parameters individually and analyse the impact on outcomes. Sensitivity analysis by varying discount rates is one such example. Sensitivity testing can lend much to the quality of the analysis, particularly in relation to highlighting the profound impact of the uncertainty of assumptions underlying parameters (Tol, 2002b).

Uncertainty will always be present because the forecasts of climate scientists and economists are based on modelling using a complex set of input parameters. Despite this uncertainty, we have enough knowledge to create credible scenarios upon which to base decision-making (ECA, 2009). Considering the profound impacts that are predicted due to climate change, decisions need to be made now despite uncertainty. One approach for dealing with inherent uncertainty in assessing climate change impacts and adaptation initiatives is to favour initiatives that increase the flexibility of systems or enhance adaptive capacity (Fankhauser et al, 1999). This means favouring 'soft' adaptation options that increase capacity to respond to a plethora of unexpected circumstances. Unfortunately 'soft' adaptation options are more difficult to cost than 'hard' options such as changes in infrastructure (Parry *et al*, 2009; World Bank, 2010).

Low probability/high impact catastrophes

It is arguably the risk of small probability yet high impact climate catastrophes that is the primary driver for action to mitigate and adapt to climate change (Jotzo, 2010; van den Bergh, 2004). Omission of low probability/high impact outcomes biases damage estimates downwards (Jotzo, 2010). However consideration of these impacts is routinely omitted from climate change impact analysis, particularly general equilibrium based analyses, because of modelling difficulties (Weitzman, 2009; Hallegatte *et al*, 2008). Weitzman (2009) argues that the treatment of catastrophes in most models is inadequate. He argues that it may not in fact be possible to adequately address these issues due to deep structural uncertainty, and that economists should not attempt to do so. Hallegatte *et al* (2008) suggest that extreme impacts ought to be treated separately from mean impacts because they require different analytical treatments and ultimately different adaptation initiatives. This position is also reflected in IPCC reports which treat disasters separately from slower onset impacts.

Conclusion

Attaching dollar values to the impacts of climate change is challenging and resource intensive (Tol, 2002a), and requires judgements. These attributes are reflected globally in the lack of comprehensive quantitative data. This report has outlined the main tools available to economists for establishing estimates of the costs of climate change. None of the methodologies outlined here are without limitations, and each has its own strengths and weaknesses. The challenges are compounded by issues such as:

- the valuation of intangibles;
- distribution and equity considerations;
- discounting;
- deep uncertainties; and
- the difficulty of incorporating low probability/high impact events..

Despite the challenges it is likely that the demand for economics-based decision-support tools will remain. It is important for economists to ensure that a) the methodology selected matches the objectives of the analysis; and b) the strengths and limitations of economic analysis are clearly articulated to end users. Table 2 summarise the key issues for production of an assessment framework.

Not every methodology will yield information useful for decisions at every level or site of decision-making. Critically, Jotzo (2010) argues that in relation to adaptation, aggregate analysis of costs and benefits will be of limited use. Instead he argues that adaptation decision-makers may benefit from partial equilibrium and integrated assessment type analyses because these can explore local situations, taking account of local circumstances and stakeholder preferences. These analyses are also far more capable of incorporating intangible values and equity dimensions that general equilibrium analysis. On the other hand, participants at the September 2010 workshop suggested that there may be demand from Victorian Government Departments for high level general equilibrium type analysis to assess costs across the state. Clearly no single cost estimation methodology will suit all purposes.

Economic methods exist for incorporating intangible assets and equity/distribution dimensions into economic impact assessments, however the fact that they are technically challenging, resource intensive and subject to deep ideological debate means they are often omitted from analyses. Despite these challenges the inclusion of intangibles and equity/distributional issues is important if an analysis is to attempt to be comprehensive about the costs of climate change. Qualitative analysis particularly complements quantitative analysis in these instances (Kiker *et al*, 2005).

The treatment of discounting and uncertainties are other key issues in the estimation of the costs of climate change. Transparency regarding how these issues are dealt with in the analysis is important for decision-makers, as is a thorough sensitivity analysis. While discussion of uncertainties and parameter sensitivity analysis detracts from the impression of economic precision (I.e. one final 'total cost' estimate), it contributes to a more useful decision-making tool.

This report has highlighted difficulties associated with incorporating estimates regarding increased frequency and severity of extreme events into slow onset impact assessments. Considering these challenges and the importance of including these impacts in decision-making (particularly in the short-medium term), a separate treatment is logical and may be the best approach for Victoria.

Table 2: Issues for an assessment framework

A framework for assessing the cost of climate change in Victoria would need to:

Take explicit account of:

- Uncertainties at all stages of the analysis;
- Intangibles including ecosystem services and human lives;
- Low probability high impact events/surprises;

Use an integrated approach to economic analysis (combining Partial and General Equilibrium Analysis);

If possible, use dynamic modeling for future projections rather than assume no change in socio-economic factors;

Give consideration to the differential impacts on sectors, regions and communities;
Equity and distributional issues;

Use sensitivity analysis including for the discount rate;

This report has highlighted the importance of ensuring that the methodology selected for an analysis meets the objectives of the end users, be they community groups, sectoral bodies, state or local government etc. If for example, a single, large Victorian study were to be commissioned it may be prudent to adopt an integrated approach. While acknowledging the limitations of economic analysis discussed above, a partial equilibrium based analysis of vulnerable Victorian sectors could be the first step. This may utilise qualitative studies such as Jones & Webb (2008) to identify which sectoral analyses are expected to be most vulnerable to climate change. General equilibrium analysis could also be undertaken if there is demand for this high level information, recognising that the different analyses generate different sorts of information, and both are decision-making tools – not prescriptions. Such a Victorian study or studies would ideally include expert and stakeholder consultations to grasp the local context. Despite the difficulties associated with intangible costs and benefits, a sophisticated and thorough economic treatment of these is not impossible and would add much to the analysis. It would also provide beneficial research outcomes for wider Victorian and Australian climate change decision-making. An integrated approach for a broad Victorian study aligns well with the approach suggested at the September 2010 VCCCAR Framing Adaptation workshop on economic costing.

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