10 THE WIDER COSTS AND BENEFITS OF CLIMATE CHANGE MITIGATION IN AUSTRALIA

Key points

An examination of the range of impacts through market processes with median expectations of climate impacts suggests that the modelling covers 65 to 85 per cent of total market impacts. Non-market impacts of climate change would be valued highly by Australians, but are not quantified in the draft report.

The insurance value of some lower probability outcomes could be extremely costly. An assessment of more extreme low rainfall outcomes for Australia, near the 10th percentile of the distribution, suggests that GDP costs could be in the order of 8 per cent in 2100, with household consumption of around 9.1 per cent in 2100, and reduction in real wages of around 14.8 per cent relative to the reference case.

Extreme economic disruption in developing countries from climate change could exacerbate severe economic effects on Australia.

The extent to which Australian mitigation is justified will be assessed by analysing the benefits of avoided climate change in the modelling and in sectors not subject to formal modelling, the insurance value of mitigation in relation to lower probability but high cost outcomes, and the value to Australians of non-market impacts avoided by mitigation. The application of a range of approaches to discounting for time will be brought into the formulation of advice on whether and how much mitigation is justified.

Chapter 9 presented an economic assessment of a number of important consequences of climate change for the Australian economy. These consequences were based on the Review's consideration of best-estimate climate change outcomes if no action were taken to reduce emissions levels.[1]

Chapter 2 discussed a framework for the assessment of the costs and benefits of climate change mitigation. Four categories of effects of costs and benefits of climate change and its mitigation were identified:

Category 1: Measured market impacts—those market impacts about which there is sufficient scientific and economic knowledge and data to allow a robust quantification; these were covered in the modelling discussed in Chapter 9.

Category 2: Unmeasured market impacts—market impacts that are in principle amenable to quantification but could not be quantified in the time available to the Review due to data and knowledge limitations.

Category 3: Additional insurance value of mitigation—extreme climate change scenarios and outcomes and the tails of the probability distributions. These impacts arise separately from the best-estimate market effects because of risk aversion: people are generally prepared to pay some insurance cost to avoid the possibility of large, adverse outcomes.

Category 4: Non-market impacts that Australians value—impacts that are not valued in conventional markets but have considerable worth to Australians.

10.1 What proportion of market impacts does the modelling include and how significant are the exclusions?

10.1.1 Measured and ummeasured market impacts of climate change

Chapter 9 presented the results of modelling the quantifiable market consequences of climate change associated with the Review's best estimate of climate change outcomes. These market impacts were chosen and modelled based on causal links with climate change, demonstrated in the applied science, available data and knowledge, or the Review's capacity to commission new and significant research in the time available. Where economic consequences were considered to be potentially high, such as for tourism, geopolitical instability and some aspects of infrastructure, but where inadequate empirical data and research were available, the Review chose not to include them as part of the economic modelling exercise.

As a result, the Review's modelling in Chapter 9 excludes a range of market impacts that, given more time and research, could be included in an economic analysis of the kind undertaken in Chapter 9. The Review looks forward to ongoing empirical research and further contributions to the modelling framework and methodology established in this draft report.

Table 10.1 provides an extensive list of the market impacts that are likely to be associated with best-estimate climate change impacts, including the set of market impacts that have been quantified in the economic analysis in Chapter 9. Categories of impacts are grouped into economic 'sectors' or characterised as 'economy wide' where impacts are not sector specific, such as international trade and commercial buildings. The table provides a qualitative assessment of the economic consequences of climate change based on each sector's direct impact and risk from climate change, as well as potential adaptive capacity. The lack of empirical evidence and research for a range of sectors and impacts means that a significant element of judgment has been used in this assessment.

As shown in Table 10.1, a number of market impacts have been excluded from the Review's modelling. However, when considered as a function of the risk associated with each direct impact, and the adaptive capacity and economic value of each sector, it is likely that these omissions may only contribute a small or moderate proportion of the likely total economic consequences of climate change.

This analysis is somewhat speculative in nature and does not allow a definitive assessment of the size of the economic consequences for excluded categories. It does, however, allow a broad evaluation of the magnitude of exclusions.

For the purposes of categorising economic consequences in Table 10.1, the Review has adopted the following definitions for low, medium and high economic consequences:

- high economic consequence: 0.5–1.5% of GDP
- medium economic consequence: 0.1–0.5% of GDP
- low economic consequence: < 0.1% of GDP.

Table 10.1 Assessing the market impacts of climate change

Sector	Direct impact	Modelled	Risk	Ability to adjust or adapt	Comment	Direct economic consequence
Economy wide—international trade	Changes to import prices	Yes	High	–	Commodity-specific shocks, but methodology overlooks sectoral dimensions of climate change.	High
	Changes to world demand (commodity specific)	Yes	High	–		
Economy wide—infrastructure	Impacts on commercial buildings—changes to building codes and planning schemes	No	High	High	Capital stock of dwellings (current prices) in 2006–07 was around $1.3 million, 40% of total capital stocks (ABS 2007a).	Medium
	Accelerated degradation of buildings—maintenance and repair costs	Yes	High	High		Medium
Economy wide—extreme events (tropical cyclones, storms/flooding, bushfires)	Increased intensity of tropical cyclones—damage to residential infrastructure and home contents	Yes	High	Medium	The current average annual cost of tropical cyclones is estimated at $266 million, a quarter of the cost of natural disasters (BTE 2001).	Low
	Increased intensity of tropical cyclones—damage to commercial buildings and business interruption	No	High	Medium		Low
	Southward movement of tropical cyclones—infrastructure and business interruption	No	High	Medium	High uncertainty regarding southward movement of tropical cyclones.	Low
	Higher frequency of storm events (e.g. flooding from non-cyclone events)—damage to infrastructure	No	High	Medium in short run High in long run	Estimated average annual cost of floods in Australia is $314 million (BTE 2001).	Low
	Bushfires—infrastructure damage, crop loss, emergency response	No	High	Low–medium	Bushfires estimated to pose an annual average cost of about $77 million (BTE 2001).	Low
Economy wide—sea-level rise	Increase in sea levels of 0.59 m, impacts on coastal settlements	No	High	High	Assessment assumes there is no significant sea-level rise this century deglaciation.	Low
Economy wide—human health	Heat-related stress, dengue fever and gastroenteritis—impacts on productivity	Yes	High	High	Assumes management and prevention of health impacts.	Low
	Other health impacts (productivity)	No	Low	High		Low
Agriculture	Changes in dry land crop production due to changes in temperature and CO_2 concentrations	Yes	High	Medium	All crops $19.5 billion (gross value of commodities) (ABS 2007b).	High
	Sheep, cattle, dairy—changes in carrying capacity of pasture from CO_2 concentrations, rainfall and temperature	Yes	High	Medium		High
	Impacts on sheep and cattle from heat stress due to temperature increases	No	Low	Medium to high		Low

Sector	Direct impact	Modelled	Risk	Ability to adjust or adapt	Comment	Direct economic consequence
	Impacts on pigs and poultry from heat stress due to temperature increases	No	Low	Medium	Limited research on potential impacts.	Low
	Irrigated agriculture—reductions in water runoff	Yes	High	Medium	Adaptation through land-use change, water conservation.	High
Fisheries	Reduced yields due to changes in water temperature	No	Medium	Low	Potential for higher adaptive capacity for aquaculture. In 2006–07, forestry and fisheries combined contributed less than 2% of total GDP (ABS 2008a).	Low
Forestry	Yields affected by water availability and CO_2 concentrations	No	Low	Low	Possibility of using other species.	Low
Mining	Slower growth in demand due to slower increase in world income (relative to a no climate change world)	Yes	High	Low	In 2006–07, the mining industry contributed 7% of total GDP (ABS 2007a).	Medium to high
	Reduction in water availability	No	High	High		Low
Tourism	International tourism affected by slower growth in demand due to slower increase in world incomes (relative to a no climate change world)	Yes	High	Low	Tourism as a share of GDP is 3.7%, which equates to $38 935 million. In 2005–06, 11% of exports of goods and services (ABS 2008b).	Medium
	Reduction in international demand for Australian tourism as a result of reduced natural amenity of tourism products	No	High	Low	Requires assumptions of changes in preferences and relative amenity versus absolute amenity.	High
	Changes in domestic tourism as a result of reduced amenity of tourism products	No	Medium	Low to medium	Domestic tourism is worth $29 028 million (2.6% of GDP) (relative to international tourism—$9907 million) (0.9% of GDP).	Low
Government (health)	Increased expenditure on prevention and treatment for dengue virus, heat stress and gastroenteritis	Yes	Medium	High	Public and private expenditure low to moderate.	Low
	Increased expenditure on prevention and treatment for other health impacts (air pollution, mental health etc.)	No	Medium	High		Low
Government (defence/aid)	Increase in defence and aid expenditure due to geopolitical instability in neighbouring nations	No	High	Low	Combined aid and defence budget for interventions in Timor-Leste and Solomon Islands, $900 million per year. Foreign aid 2006–07, 0.3% GNI (AusAID 2006). Defence expenditure 2006–07, $17 billion (ABS 2007c).	Medium

Table 10.1 Assessing the market impacts of climate change *(continued)*

Sector	Direct impact	Modelled	Risk	Ability to adjust or adapt	Comment	Direct economic consequence
Residential dwellings	Building degradation and damage resulting from temperature, rainfall, wind etc. Changes to building codes and increased maintenance and repair	Yes	High	High	Costs of adaptation likely to be high.	High
	Impacts on buildings due to extreme events (e.g. flooding)	No	High	High	Costs of adaptation likely to be high.	Medium to high
Transport	Degradation of roads, bridges and rail due to temperature and rainfall	No	High	High	In 2004–05 maintaining and improving the total road network cost $9 billion (BITRE 2008).	Low
Ports	Port productivity and infrastructure affected by gradual sea-level rise and storms	Yes	High	High		Low
Airports	Impacts on infrastructure due to sea-level rise, temperature and rainfall	No	Low	Medium		Low
Tele-communications		No	Low	High	Telecommunication services industry contributed about 2.5% of GDP in 2006–07 (ABS 2007a).	Low
Water supply	Decrease in rainfall reduces reliance on traditional water supply for urban uses and increases demand for alternative water supply options	Yes	High	High	High costs associated with adaptation options.	Low to medium
	Degradation of water supply infrastructure increases maintenance costs	Yes	High	High		Low
Electricity transmission and distribution	Degradation of infrastructure increases maintenance costs Productivity losses from blackouts due to severe weather events	Yes	High	High		Low
Electricity generation	Increased demand for electricity resulting from greater use of air conditioners	No	High	High	New generation costs. Net capital expenditure for the electricity supply industry increased in 2005–06 by $1.7 billion (27%) to $8.1 billion (ABS 2006).	Low to medium

10.1.2 Modelled market impacts

As discussed in Chapter 9, the Review has attempted to capture the majority of market impacts that were considered to have potentially significant economic consequences from climate change. Impacts were captured across a range of areas including:

- international trade
- primary production
- human health
- infrastructure
- tropical cyclones.

As shown in Table 10.1, there are a number of market impacts omitted from the categories of impacts that were modelled in Chapter 9. The most significant of these omissions are discussed below.

Human health

While a significant proportion of the total adverse impacts on health from climate change were excluded from the economic analysis in Chapter 9, the Review does not consider this to be significant in terms of economic consequences. Even if the modelled costs discussed in Chapter 9 were to double to reflect the excluded impacts, the net economic consequences from climate change would still not be large.

While the excluded health impacts are not considered to represent large economic consequences, they may represent considerable non-market effects.

Infrastructure

The Review has modelled the market impacts associated with four key infrastructure categories—buildings in coastal settlements, ports, electricity transmission and distribution, and urban water supply infrastructure in major cities.

As shown Table 10.1, there are several infrastructure-related exclusions in the modelling. Of these, the most significant are likely to be additional increases in the cost of building construction (both commercial and residential) as a result of new building design requirements that have not already been modelled, and increased road and bridge maintenance. The need for increased peak power usage to cool buildings may also be a significant omission.

To understand the possible implications of omitting these impacts, some simple calculations can be useful.

Residential and commercial buildings make up a large proportion of the economy's capital stocks, and hence a large proportion of expenditure is made on their maintenance, upgrade and construction. This means that even relatively small impacts can have large economic consequences. For example, a 5 per cent increase in the cost of constructing and maintaining buildings may have the effect of reducing GDP by as much as 0.8 per cent.[2]

While the Review has captured some of the impacts of climate change on building infrastructure (degradation of materials and insulation and double-glazing costs for dwellings) other significant costs may have been omitted (such as additional changes to building codes to cope with increased cyclone activity and temperature and rainfall extremes).

Evidence suggests that climate change is likely to increase the rate at which roads and related infrastructure degrade. Australia's road network is large. For example, it covers 812 000 kilometres and comprises over 37 000 bridges. If the cost of maintaining the road network were to increase by 25 per cent, GDP might be reduced by around 0.25 per cent.[3]

Agriculture

The estimated economic impacts on agriculture presented in Chapter 7 arise from average changes to climate variables. It is likely that climate change will affect the variability and predictability of the climate, as well as the average. This is particularly relevant for rainfall. More frequent droughts could have very different economic consequences than general reductions in precipitation of similar average effect.

In the absence of forecasts describing the level of future variability, it is difficult to provide an estimate of the degree to which increased climate variability would affect the economy.

Tropical cyclones

The modelling of the impacts of the anticipated increase in intensity of tropical cyclones includes only estimates of the costs to residential buildings and contents. It does not include impacts to commercial and industrial buildings or an assessment of business interruption and clean-up costs. However, it is unlikely that the inclusion of these costs would change the economic consequences of climate change significantly, since the modelled impacts (on a whole-of-economy scale) are relatively small. As noted in Chapter 9, the individual impacts from cyclones contribute only a small amount to the overall decline in consumption.

Also excluded from the analysis was the possibility of a southward movement in cyclone genesis. While there is no general consensus about the southward shift in cyclone genesis, research suggests that Australian tropical cyclones may move further south in Queensland, and hit the Australian coastline with greater intensity (Leslie et al. 2007). Since population densities are higher in the southern reaches of Australia's tropical regions (particularly south-east Queensland), there may be considerable costs associated with such changes.

Estimates by Geoscience Australia for the Review suggest that a single category 3 cyclone hitting the Gold Coast today could cause up to $7.5 billion in damage to houses alone. Allowing for commercial and other property damage as well as business disruption costs, this figure could climb as high as $25 billion.

An estimate by Munich Re Group (2006) suggests that if a tropical cyclone like Dinah (category 3, 1967) were to hit Brisbane, the Gold Coast and the Sunshine Coast now, the potential insured losses would be in the range $10–17.5 billion.

While the social and regional economic effects would be significant, such an event is unlikely to result in a large, economy-wide effect. In a trillion-dollar economy, a $25 billion repair bill could amount to a reduction of GDP in a single year of around 2 per cent. Economic activity could be expected to return to normal levels once infrastructure was repaired. The availability of insurance will spread much of the cost through time. Even if an event of this magnitude were to occur every 25 years, the annualised losses would be expected to be in the order of 0.1 per cent of GDP.

International trade

As discussed in Chapter 9, the Review has undertaken global modelling of climate change using the Global Integrated Assessment Model (GIAM) developed jointly by ABARE and CSIRO. This model was linked to the domestic modelling (the Monash Multi Regional Forecasting, or MMRF, model) by imposing the implied changes in world demand and import prices projected by GIAM.

While this methodology captures the broad implications of climate change effects for Australia, the results from GIAM are subject to a number of caveats. At this stage of its development, GIAM uses a highly simplified climate impact damage function. Regional climate change damages are assumed to be a function of regional changes in average temperature (relative to 2000) and the vulnerability of a region to potential climate change. Economic loss factors are applied as negative shocks to total factor productivity and do not differentiate between economic sectors in their impacts. As a result, impacts to agriculture from climate change are determined in the same way as impacts to services sectors. This means, for example, that detailed modelling cannot be applied to estimation of the impacts of climate change on food production. Further development and improvement would allow for sector-specific damage functions as well as the inclusion of responses to additional climate variables.

10.1.3 Market impacts that have not been modelled

As shown in Table 10.1, there are a range of impacts and sectors that have not been included in the Review's modelling. Of these, it is likely that impacts on tourism and geopolitical stability, and increased construction costs for buildings, will be among the most significant in terms of their effects on production and consumption of goods and services.

Tourism

International tourism is likely to be affected by climate change through three main channels: global incomes, relative prices, and environmental and social amenity. While the Review has captured the first two of these factors through its global modelling, the third has not been considered at all in the modelling.

As discussed in Chapter 7, climate change is likely to have significant impacts on environmental amenities that are important for tourism, for example, the Great Barrier Reef, south-western Australia (a biodiversity hotspot) and Kakadu. While it has been possible to assess the likely impacts of climate change on these environmental assets qualitatively, it has not been possible to estimate the likely effect this will have on international tourism.

Despite the difficulty of estimating the effect of climate change on tourism, it is likely that even small changes could have significant effects. International travel to Australia is projected to increase sharply as global incomes rise. In 2005–06 approximately 11 per cent of total exports were tourism related. This share is expected to rise substantially over the coming decades as incomes and the value of exports rise. This suggests that even small changes in demand may have significant economic implications.

While domestic tourism is also likely to be affected by climate change, this is, in the main, likely to be felt through regional changes rather than nationally. Unless Australians choose to spend less of their incomes on recreational activities, climate change may result in a change in the type of tourism activity rather than the absolute level of tourism.

A loss of environmental amenity in Australia may also cause a preference shift towards overseas travel. However, this is impossible to quantify, without making highly speculative assumptions about changes in consumer preferences.

Defence expenditure and geopolitical stability

Climate change is likely to result in both gradual changes and extreme climate events that will affect Australia's neighbouring developing countries. As discussed in Chapter 7, food security issues, severe weather events, sea-level rise, climate refugees, and energy and water security issues can contribute to increases in geopolitical instability.

It is likely that an increase in geopolitical instability in the Pacific region, and the globe generally, will require an increase in the capability and requirements of Australia's defence forces, and an increase in the level of Australia's spending on emergency and humanitarian aid abroad. These measures will reduce the income available to households and consequently reduce consumption.

In 2006–07 total expenditure on defence was approximately $17 billion. If climate change caused defence expenditures to increase by 10 per cent, this would imply the need for an additional $1.7 billion to be raised by government. In 2004–05 total household consumption was around $580 billion. Therefore, an increase in defence expenditure in the order of 10 per cent might reduce household consumption by around 0.3 per cent.

Previous Australian interventions in small neighbouring nations may also provide an indication of the potential size of future defence costs that may arise from climate change. It is likely, however, that climate change could lead to geopolitical pressures involving larger countries, and thus may lead to much higher spending than would be indicated by recent history.

The combined aid and defence budget for the five-year intervention in Timor-Leste, starting in 1999–2000, has exceeded $700 million per year. Australia's intervention in Solomon Islands is estimated to cost around $200 million per year (Wainwright 2005). This intervention, which started in 2003, is likely to continue until at least 2013, with the possibility for ongoing significant support.

The combined expenditure on regional defence force interventions has averaged over half a billion dollars per year since 1999 (M. Thomson 2008, pers. comm.).

Climate change may also require an increase the level of foreign aid to developing countries. Foreign aid expenditure in Australia is currently relatively small. In 2007–08 official foreign aid expenditure was only 0.3 per cent of gross national income. Aid expenditure would therefore have to increase substantially to have a large impact on welfare in Australia.

10.1.4 Size of market impacts associated with best-estimate climate change outcomes

The modelling discussed in Chapter 9 showed that the market impacts of unmitigated climate change that were able to be measured by the Review are projected to result in a decline in GDP, household consumption and real wages of 4.8 per cent, 5.4 per cent and 7.8 per cent respectively, relative to a reference case without climate change.

As discussed above, there are a range of market impacts that were not able to be estimated for inclusion in the modelling. As shown in Table 10.1, most of these impacts are relatively minor or the costs of adaptation and adjustment are considered to be relatively small. However, as discussed above, there are a small number of impacts that may have significantly increased the modelled impacts had they been included. The key impacts omitted include some infrastructure spending, impacts on tourism from a loss of environmental amenity, increased defence and foreign aid expenditure, and the effects of greater climate variability, reduced predictability on agricultural production and the cost of supplying water.

While a lack of quality data and a lack of understanding of the relationship between climate change and economic impacts make it difficult to quantify the magnitude of the economic implications associated with these omitted market impacts, sensitivity testing under sensible assumptions and simple estimates can provide insights into their relevance.

Based on the above discussion and simple calculations, it is possible, using the criteria outlined in section 10.1.1, that the omitted market impacts could contribute an additional 1 to 3 percentage points to the loss of welfare, as measured by household consumption. This suggests that the Review's modelling of median climate change outcomes may have captured in the range of 65 per cent to 85 per cent of market impacts.

These conclusions are based on a number of limitations and caveats, as discussed in Chapter 9.

10.2 Insurance costs of climate change mitigation—extreme climate change scenarios

The uncertainty about climate change and its environmental and socio-economic impacts introduces a wide distribution about the mean of possible outcomes. At the more extreme end, it is likely that climate change would introduce impacts that might be considered to be large, and perhaps catastrophic. In addition, the economic and social responses to these lower-probability climate outcomes could also be extreme.

Chapter 5 discussed in detail the possibility of severe and irreversible impacts on the world's climate by 2100 under a range of global emissions pathways. The higher temperatures associated with an unmitigated global pathway increase the likelihood of the occurrence of more extreme outcomes. Some of the extreme outcomes and consequences discussed in chapters 3, 5, 6 and 7 that are likely to have economic consequences for Australia, either directly or indirectly, include faster sea-level rise resulting from the melting of the Greenland and West Antarctic ice sheets; changes to the El Niño – Southern Oscillation; melting of the Himalayan glaciers; failure of the Indian monsoons; and temperature and rainfall outcomes towards the hot and dry ends of the probability distributions from the mainstream science.

Flowing from these extreme climate outcomes is the possibility for extreme environmental, social and economic responses. Tipping points and the occurrence of one or many of the extreme outcomes described above could trigger extreme consequences or responses in many countries.

For Australia, the possibility of extreme climate outcomes could be felt directly through extreme temperature, rainfall and other climate responses (e.g. sea-level rise, heatwaves and flooding), as well as indirectly through international trade and regional geopolitical instability.

As discussed in Chapter 2, an aversion to risk suggests a willingness to pay a higher price to avoid climate change than would be suggested simply by examining best-estimate climate outcomes.

However, there is considerable difficulty associated with considering outcomes that are far from the mean due to the uncertainty behind the likelihood, timing and extent of such outcomes. What can be said with confidence, as discussed in Chapter 5, is that with each additional increment of temperature change the likelihood of an event occurring increases.

When considering extreme climate change outcomes, the impacts, both environmental and economic, can be predicted with much less certainty. As temperatures rise above historical highs, and as climate events occur with increasing severity and frequency, it is increasingly difficult to predict impacts and economic agents' responses to them.

While accepting these uncertainties, the Review sees value in attempting to quantify some extreme outcomes and responses in order to adequately understand the potential costs of climate change.

To inform this risk assessment, the Review has considered a range of extreme climate change outcomes that could directly affect Australia. In addition, consideration has been given to the possibility of extreme outcomes internationally and their flow-through effect on Australia.

10.2.1 International trade—effects of enhanced impacts in developing nations

Developing countries are likely to be particularly vulnerable to climate change. These nations are more reliant on sectors susceptible to climate change (particularly agriculture) and are likely to have less adaptive capacity than more developed nations. Less stable political systems may also mean that societies could fracture in response to extreme climate change impacts. Asian developing countries, in particular, are vulnerable to sea-level rise and disruption of established patterns of rainfall and river flows.

Severe shocks can destabilise governance in developing countries and lead to regional conflicts. Shocks from climate change could be much larger than shocks of other kinds that have been seriously destabilising in the past.

To get an idea of how large the consequences of these disruptions might be, the Review has examined major historical events over the past two decades.

Chinese output fell by approximately 6.6 percentage points from its trend during the 1989–90 political crisis. Output of the Southeast Asian economies fell by about 12.0 percentage points below trend during the Asian financial crisis of 1997–98.

Might climate change bring on dislocations that are similar in magnitude to those in China two decades ago and Southeast Asia one decade ago? The inflationary impact of a dislocation of agricultural production as a result of disruption to the south Asian monsoon, or a break in the flows of the great rivers that have their origins in the Himalayas, would seem to be rather more disruptive than the triggers for short-term growth crises in east Asia over the past two decades. Major cyclonic events, superimposed on sea-level rises near the upper end of the range of possibilities, would be highly disruptive. Inflexibility in political and economic institutions could be expected to magnify the critical economic shock in many developing countries—as it did the inflationary shock in China in 1989, or the exchange rate shock in Southeast Asia in 1998, or, for that matter, the financial shocks in central Europe in the early 1930s and in Australia in the 1890s and 1930s.

It seems reasonable to assume that output growth lost in these circumstances is not recovered—as seems to have been the case in Southeast Asia in the 1990s. Indeed, growth in all Southeast Asian economies settled onto a substantially lower trajectory after the financial crisis.

The shocks to China in 1989–90 and to Southeast Asia in 1997–98 had large consequential effects on growth in Australia. The possibility of more widespread shocks associated with problems in developing countries' adjustment to climate change will be examined further. To illustrate the potential importance of these factors, the Review modeled a shock to India and China of the dimension of the 1989–90 China crisis, and to other developing countries of the dimension of the Southeast Asian financial crisis, after 20 years and repeated at intervals of 20 years. This would reduce Australian GDP in 2100 by more than 8 per cent relative to the reference case, and consumption by around 12 per cent.

10.2.2 Extreme rainfall outcomes

In Australia, changes in the frequency and intensity of rainfall and temperature extremes are projected to occur more rapidly than changes in the equivalent means (Chapter 3). While average temperatures in Australia are expected to rise in parallel with rises in global mean temperature, there are significant regional variations.

For rainfall, variability and uncertainty is pronounced due to the many localised influences on rainfall outcomes. Rainfall at the 10th percentile at the dry end of the distribution in the unmitigated scenario is projected to decline much more than at the 50th percentile in many parts of Australia. But at the wet end of the distribution, the 90th percentile, average rainfall in Australia increases a little from current levels.

At the global level there is considerable uncertainty as to how sensitive the climate is to changes in carbon dioxide concentrations (Chapter 3). A best-estimate climate sensitivity of a 3°C rise in response to a doubling of carbon dioxide concentrations has been defined (IPCC 2007), but much higher outcomes are possible. All the scenarios modelled and investigated by the Review for the Australian impacts analysis used the best-estimate climate sensitivity.

At the local level, a range of temperatures are possible in response to a given global increase. The best-estimate median unmitigated scenario discussed in Chapter 7 assumes a best-estimate rainfall and local temperature response to global change. Uncertainty in how the Australian climate will respond to a given global temperature is incorporated by considering a 'dry' rainfall sensitivity (relative to the median rainfall estimate) combined with a 'hot' temperature outcome. This sensitivity is associated with the 10th percentile rainfall outcome for Australia combined with a 90th percentile temperature outcome for Australia. Both are considered in the context of the same global mean temperature of 4.5°C by 2100. The climate variables associated with the dry scenario are discussed in Chapter 6.

As discussed in earlier chapters, there is a complex link between rainfall and temperature. This means that for any given global temperature, numerous combinations of local rainfall and temperature changes are possible. Based on this observation, and the advice of the CSIRO (R. Jones & S. Hatfield-Dodds 2008, pers. comm.), the hot, dry climate change scenario is considered to be a plausible outcome to investigate extreme rainfall changes for Australia under an unmitigated scenario.

The sector of the economy most sensitive to changes in rainfall is agriculture. Australia is already a dry country. Declines in rainfall (and increases in rainfall variability) will make it increasingly difficult to produce food. As discussed in Chapter 9, the impacts under the median unmitigated scenario are sizeable.

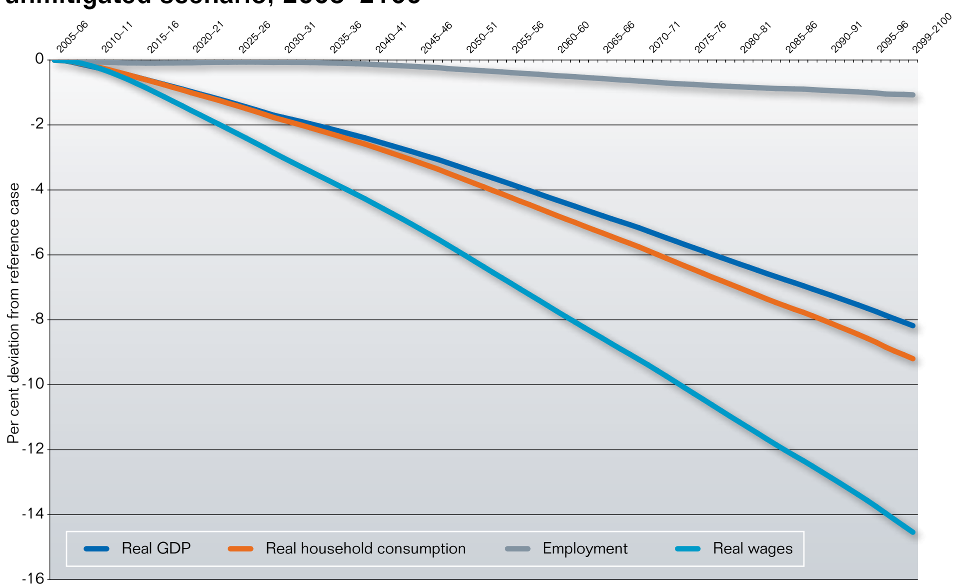
As evident in Table 6.2 in Chapter 6 under the hot and dry unmitigated scenario, much more severe reductions in rainfall are projected than under the median. This analysis focuses on the dry end of the range of possibilities with a 10 per cent probability of outcomes being this dry or drier. For example, rainfall declines by 28 per cent by 2050 and 70 per cent by 2100 in South Australia. These extreme rainfall changes lead to even higher reductions in streamflow. In many parts of the country, established river systems would simply cease to flow. The ability of both economic and biophysical models to accurately project impacts under these kinds of changes is limited. Despite this uncertainty, the projections for the dry scenario provide a picture of a possible economic future under a hot and dry unmitigated climate change scenario.

Under this scenario the economic impacts are substantially higher than for the median unmitigated scenario. By 2100, GDP is projected to fall by nearly 8.2 per cent, relative to a reference case with no climate change. Real household consumption falls by 9.1 per cent in 2100, relative to the reference case, and real wages by 14.8 per cent. Table 10.2 provides some key macroeconomic projections for this scenario. These projections are represented graphically in Figure 10.1.

Table 10.2 Projected macroeconomic effects of climate change, hot, dry unmitigated scenario (per cent deviation from reference case)

Variable	2020	2050	2100
Real GDP	-0.9	-3.2	-8.2
Real gross national expenditure	-0.9	-3.4	-8.6
Real household consumption	-0.9	-3.5	-9.1
Export volumes	-0.7	-2.1	-4.6
Import volumes	-0.4	-1.4	-3.7
Terms of trade	0.0	-0.3	-1.8
Real wages	-1.4	-5.8	-14.8

Figure 10.1 Changes to select macroeconomic variables, hot, dry unmitigated scenario, 2005–2100



10.3 Non-market impacts that Australians value

Table 10.1 provided an assessment of the market impacts of climate change for a range of climate change impacts and sectors of the Australian economy. What was excluded from that assessment was the consideration of non-market impacts that could result from those climate change impacts.

For example, for health, one of the possible impacts of climate change could be an increase in mortality. This is likely to have both market and non-market consequences. The loss of life or quality of life is a non-market impact and cannot be adequately captured in a modelling framework of the type used by the Review. The market impacts, on the other hand, may include a reduction in the labour force, a reduction in labour productivity and an increase in the requirements for health services. The results of modelling these market impacts have been presented in Chapter 9.

A range of non-market impacts will also result from the extinction of species or loss of environmental amenity, as many Australians place value on them. The loss of environmental amenity, such as the degradation of the Great Barrier Reef or the loss of a particular species of flora and fauna, could also have market impacts through reductions in the demand for tourism and recreation.

Reductions in the availability of water for urban uses may also have considerable non-market impacts. Households and communities may be required to reduce their consumption of water for recreational purposes.

In this discussion, and the Review's consideration of non-market impacts, the value of non-market services is defined by the value placed on them by Australians, as opposed to their intrinsic ecological value to other species.

There are a broad range of non-market impacts that are likely to feature prominently in Australians' valuation of the impacts of climate change. These includes impacts on:

- biodiversity
- health and longevity
- valued environments of many kinds
- unique environmental assets
- environmental support for established social and cultural institutions.

Chapter 2 discussed the utility of Australians in the context of non-market impacts. The discussion introduced the concept of a utility function that rises with Australians' consumption of goods and services, as well as with a number of non-monetary services. As incomes and consumption rise, non-market values are likely to become 'superior' goods. In other words, the relative value people assign to non-market values rises with income. As incomes and consumption rise over time—and the reference case has average consumption of material goods and of services rising ninefold over the 21st century—the substitutability of non-market services for conventional consumption diminishes. This implies a loss in utility from the occurrence of any one of the non-market impacts discussed above.

The consideration of non-market impacts is therefore an important component of assessing the consequences of climate change and the benefits of climate change mitigation.

It is possible to assess the monetary consequences associated with non-market impacts using alternative valuation techniques. Rothman et al. (2003)

provide a brief discussion of the range of techniques used to value non-market services. The majority of these techniques focus on implicit values that can be determined from surrogate or constructed markets. For example, hedonic pricing attempts to value non-market goods and services by comparing market prices, such as housing. In some cases, these prices can act as proxies for values placed on environmental quality, such as higher prices for housing in suburbs endowed with high environmental quality.

There are many complexities associated with non-market valuation techniques and current examples that attempt to assign monetary values to non-market services. The Review is not seeking in this draft report to estimate the value of non-market impacts to Australians, but is instead aiming to present the broad issues raised by their existence, and their implications for the evaluation of the costs and benefits of climate change mitigation. These issues will be discussed further in the supplementary draft report and final report, when we can bring together our assessments on these matters with the results of the modelling of the conventional economic benefits and costs of varying degrees of mitigation of climate change.

10.4 Assessing the costs of climate change beyond 2100

The Review's modelling of best-estimate climate change outcomes, as well as the evaluation of the extreme end of the probability distribution discussed in this chapter, was only able to project results to 2100. As noted in Chapter 2, the effects of climate change, and the effects on things that are valued by humans living today, do not end at the conclusion of the 21st century.

As evident from the analysis of projected changes to GDP and consumption through time in this chapter and Chapter 9, the economy does not stabilise at some new growth path by 2100 (see Figure 10.1 and Figure 9.3). This is not surprising since emissions are still growing, the climate is still changing and climate-related impacts are still unfolding.

Risk management therefore necessitates an evaluation of costs and benefits over much longer time frames. The weight that is ultimately attached to these longer-term effects depends on the discount rate. Discount rates, and the sensitivity of policy assessments to them, will be introduced to the analysis in the supplementary draft and final reports.

10.5 Implications for evaluating the costs and benefits of climate change mitigation policy

The Review's economic analysis up to this point has focused on the costs associated with unmitigated climate change. Chapter 2 discussed the next steps in the Review's approach to modelling climate change mitigation.

The Review's ultimate aim is to assess the costs and benefits to Australia of global mitigation to stabilise greenhouse gas emissions at 450 ppm and 550 ppm carbon dioxide equivalent, as a basis to providing advice on whether and to what extent mitigation is justified by the assessment of its costs and benefits.

As indicated in Chapter 2 and discussed in this chapter, the consideration of the extreme ends of the probability distribution, as well as the recognition of the range of non-market impacts of climate change, will be integral to the conclusions presented in the final report.

Notes

1 For the purposes of the modelling, the Review determined best-estimate climate change outcomes as the 50th percentile rainfall and 50th percentile temperature outcomes associated with mean global temperature change under an unmitigated climate change scenario. These outcomes are associated with the median of the rainfall and temperature probability distributions.

2 An increase in the cost of constructing and maintaining buildings is equivalent to a productivity loss since more capital inputs per unit of output would be required. If buildings make up around 40 per cent of capital stocks, and capital incomes make up approximately 40 per cent of total income, then a 5 per cent reduction in productivity of building stock would be expected to reduce GDP by approximately 0.8 per cent.

3 GDP in 2004–05 was just under $900 billion. If road expenditure were to increase by 25 per cent or $2.25 billion, GDP might be reduced by around 0.25 per cent.

References

ABS (Australian Bureau of Statistics) 2006, Electricity, *Gas, Water and Sewerage Operations, Australia, 2005–06*, cat. no. 8226.0, ABS, Canberra.

ABS 2007a, *Australian System of National Accounts, 2006–07*, cat. no. 5204.0, ABS, Canberra.

ABS 2007b, *Australian Farming in Brief, 2007*, cat. no. 7106.0, ABS, Canberra.

ABS 2007c, *Government Finance Statistics*, cat. no. 5512.0, ABS, Canberra.

ABS 2008a, *Australian National Accounts: Input – Output, 2004–05 (preliminary)*, cat. no. 5209.0.55.001, ABS, Canberra.

ABS 2008b, *Australian National Accounts: Tourism Satellite Account, 2006–07*, cat. no. 5249.0, ABS, Canberra.

AusAID 2006, A*ustralia's Overseas Aid Program Budget 2006–07*, Commonwealth of Australia, Canberra.

BTE (Bureau of Transport Economics) 2001, *Economic Costs of Natural Disasters in Australia*, Report 103, BTE, Canberra.

BITRE (Bureau of Infrastructure, Transport and Regional Economics) 2008, 'Information Sheet 27: Public road-related expenditure and revenue in Australia (2008 update)', Commonwealth of Australia, Canberra.

IPCC 2007, *Climate Change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor & H.L. Miller (eds), Cambridge University Press, Cambridge and New York.

Rothman, D.S., Amelung, B. & Polomé, P. 2003, 'Estimating non-market impacts of climate change and climate policy', paper prepared for an OECD workshop on the Benefits of Climate Policy: Improving Information for Policy Makers, Paris, 12–13 December 2002.

Leslie, L.M., Leplastrier, M. & Buckley, B. 2007, 'Estimating future trends in severe hailstorms over the Sydney basin: a climate modelling study', *Atmospheric Research* 87(1): 37–51.

Munich Re Group 2006, *Topics Geo: Natural catastrophes—analyses, assessments, positions*, <www.munichre.com/en/publications/default.aspx?id=1060>, accessed 25 June 2008.

Wainwright, E. 2005, 'How is RAMSI faring? Progress, challenges, and lessons learned', *Australian Strategic Policy Institute Insight* 14.