Costing Climate Change in Canada: Impacts and Adaptation

This paper has been prepared under the direction of Ian Burton.
It builds upon an earlier paper prepared for the Canada Country Study.
The authors are listed alphabetically and the paper may be cited as Bein, P. et. al.

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Executive Summary and Recommendations

- The level of knowledge about the economic costs of climate change impacts and adaptation, actions that might be taken is rudimentary and unreliable. (Section 3).

Subject to many caveats it can be said that for the developed industrial economies including Canada, GDP would be reduced by 1% to 1.5% with an equilibrium atmospheric concentration of CO2 equivalents double that of pre-industrial levels, and with an expected global mean temperature increase of 2.5 degrees C. Very little consideration of specific impacts upon Canada has employed in the development of this estimate. Among the industrialized countries Canada is one of the few (others include Russia, the Baltic countries and Scandinavia) that can also expect to experience significant benefits from climate change. Canadians now spend in the order of 1.5 - 2% of GDP on adapting to current climate, or a total of $11 billion, or approximately $360.00 per capita per year. This total is likely to increase sharply with climate change.

- Serious efforts are needed to improve upon existing knowledge of the costs of impacts and adaptations.

However, the intractable nature of the climate problem itself and the inappropriateness of standard economic methods such as benefit-cost analysis, means that substantial improvements are not to be expected in the near future. An analysis of the reasons why the state of economic knowledge is so unsatisfactory and is likely to remain so in the near future is presented in Section 4.

- The development of improved understanding of the costs of climate change impacts and adaptations requires the creation of an integrated assessment and adaptation science capability.

This has been underway for some time in other countries where integrated modeling and the integration of adaptation science are now more advanced. Canadian research is not as strong as it could be in these areas and Canadian contributions have so far been relatively small. This research area needs to be strengthened if Canada is to play its role in international negotiations, and develop its own policy appropriately. (Sections 2, 5)
- There are a number of interim steps that can be taken now to improve understanding of the costs of climate change, as well some alternative approaches that can be developed, in addition to the longer term research agenda. (Section 5.)

We suggest four approaches that can be used to improve on existing cost estimates; these are historical and spatial analogues; cost estimates based upon input-output models; valuation of ecosystem services, and integrated assessment. While further research in these directions is needed quick results cannot be expected. As interim steps we suggest greater systematic attention to the current costs of climate variability and research on vulnerability and adaptive capacity. Given the difficulties in developing reliable cost estimates we identify three additional approaches that could be employed to assist decision makers and the policy process. These are risk assessment, multi-objective decision analysis, and valuation constrained by (in the context of) sustainability.

- Research needs and priorities for action that could be included in the National Climate Change Strategy are as follows.

1. Strengthen the research capacity to advance understanding of the costs of impacts and adaptation, especially in integrated assessment and adaptation science.
2. Focus the research initially on the four most promising approaches; historical and spatial analogues; costs estimates based upon input-output models; valuation of ecosystem services; integrated assessment.
3. As an interim measure support activities to collect data, and make assessments of the costs of current climate and adaptive capacity, including the capacity to take advantage of new opportunities.
4. Simultaneously develop alternative approaches for policy development purposes including risk assessment, multi-objective decision analysis, and valuation in the context of sustainable development.
1. Purpose and Organization of Paper

This paper provides a summary of what is known in economic terms about the potential future changes to the Canadian economy, society, and environment that might be caused by climate change. This information is one of many inputs to the unfolding policy process. The Canada Country Study has explored the topic (Rothman et al. 1998) and this paper builds upon that work. Since the state of knowledge is shown to be rudimentary and unreliable, the present paper explains why this is so and suggests what steps might be taken to provide a better basis for policy in the absence of reliable information.

Four cost components bear on the economic significance of climate change:
- the future stream of costs and benefits that would be imposed by changing climate in the absence of any policy response;
- the continuing costs of slowing down the rate of change (mitigation costs);
- the costs and benefits of progressively adapting to those climate changes not prevented by mitigation; and,
- the residual costs which will remain after an appropriate mix of mitigation and adaptation measures is taken.

This paper focuses on impact and adaptation costs and benefits. Although it is believed that the overall impacts of climate change will be negative, there could also be substantial benefits. In all regions and sectors there will be a mix of costs and opportunities. For some regions and some sectors the net effect may actually be beneficial. The economic benefits will not be realized, unless Canadians set out to make use of them. Taking advantage of the opportunities of climate change requires effort, initiative, and investment, the costs of which must also be considered in examining the effects of climate change on Canada.

Impact costs are of two kinds: those likely to be experienced without policy-led adaptation or mitigation (costs of inaction), and those remaining after some mitigation and adaptation measures have been taken. 'Cost of inaction' is somewhat misleading in reference to adaptation because adaptation to a varying climate is an ongoing process that will continue to some extent even without policy response. The key concepts of impact and adaptation are defined in Section 2.

Section 3 presents existing estimates of impact and adaptation costs derived by various, albeit limited, methods for Canada. Section 4 reviews and assesses the methodological and conceptual problems associated with existing methods. Section 5 suggests several ways of improving the estimates, and some interim steps to provide input in other ways into decisions and policy analysis of climate change. Section 6 specifies needs and priorities for continuing work on the subject.

2. The Nature of Impacts and Adaptive Response

2.1 The Costs of Normal Climate
Climate change is sometimes characterized as a totally new threat. While the projected rate and magnitude of climate change is unprecedented, it is nevertheless true that human beings have always had to contend with changing and variable climates. It is necessary therefore to make a distinction between 'normal' climate including natural climate change and variability and anthropogenic climate change. In this paper 'climate change' refers to human-caused changes in climate. The climate in its unmodified state, including its natural variation over time, is referred to as 'normal' climate.

All countries experience economic loss from normal weather and climatic conditions. All countries have adaptation measures in place and apply them routinely in order to reduce damage caused by normal climate. Viewed from the perspective of human history, the process of adapting to climate has been extremely successful. Viable human societies and productive economies have been established in an extremely wide range of climatic conditions.

Although Canada has one of the widest ranges and extremes of climate in the world, adapting to current climate is often taken for granted. Adaptation to present day climate represents the outcome of a slow accumulation of policies and practices that are intended to protect people and property, while allowing economic and social activities to continue with a minimum of loss or disruption. Adaptation costs tend to be incorporated into routine expenditures and budgets. With climate change, it is expected that this 'built-in' cost will change, as the level of adaptation itself changes depending upon the magnitude and speed of global warming.

The population of Canada has grown through immigration of people from many different climates who have been able to adapt their culture and livelihood. The economic growth of Canada has also involved the development and adaptation of technology appropriate to the climate. These cultural, behavioral and technological changes have taken place at economic, social and environmental costs, but the overall success of the process is unquestionable. Experience supports the notion that adaptive social capacity exists, and that a spontaneous adaptation will occur even without public intervention.

The immediate perspective is less encouraging. While considerable potential for adaptation exists, there is little information about what would Canadians be adapting to and when, what responses might be chosen, how much they are likely to cost, and what impacts would remain after adaptation. In seeking to minimize the costs of climate change to Canada it is therefore imperative to have a better understanding of what can be accomplished by adaptation, at what cost, and what residual impacts could be expected after adaptation of Canadian society and natural resources.

2.2 Climate Change Impacts, Costs and Benefits

The impacts of climate change have been described as a chain of consequences caused by increased greenhouse gas concentrations in the atmosphere. These can be classified as
first, second and third order impacts. The first order impacts are the direct consequences for other environmental processes closely linked to the atmosphere, such as,

- all stages of the hydrological cycle,
- changes in the extent of permafrost, and
- the distribution of ecosystems and species.

First order impacts affect virtually all natural processes and conditions, but there is no agreement about how to measure the costs and benefits in monetary terms, and the largest first order impacts might be non-monetary. The fact that Canada’s natural capital will be changed in many ways is probably best expressed in physical and biological terms.

Second order impacts include next step consequences in those economic sectors most closely dependent on environmental conditions. The second order impacts take different forms and are difficult to trace. For example, forests may be damaged because some tree species will no longer survive in their present location, due to changes in temperature and precipitation, distribution of insect pests and disease vectors, or increased incidence of forest fires. The combined effect of these changes may result in significant geographical and structural shifts in the forest products industry, loss of some species, and corresponding decline in biodiversity.

Third order impacts refer to the change in economic values associated with first and second order impacts. Thus there may be employment and production losses in the forest industry, loss of recreational and amenity values of a degraded forest, and gains in agriculture encroaching on the retreating forests. Further impacts extend like a growing circle of waves across the economy and might involve the forest machinery supply industry, forest products transport, the balance of trade, and so on. To capture all these cost entails following the “waves” into service sectors such as finance, banking and commerce. The higher order impacts could be widespread, but some of them would be less important than initially assumed, for example, the insurance industry would spread the risk onto the insured to prevent loss of profits (Tol 1998).

The aggregation of costs of first and higher order impacts across all regions and sectors in Canada could be an enormous task, without a guarantee of reliable results. Meaningful aggregated national results are not obtainable with alternative means, because the national total is a sum of local and sector costs and benefits. Alternative approaches using macroeconomic models (Sections 3 and 4) yield aggregate “ball park” estimates of the net impact on the national economy, but they are of little value at the specific project, sector or regional level. Present-generation macroeconomic models are unable to include non-market accounts in the standard measures of economic sector inputs and outputs, yet these accounts may represent the most significant residual impacts of climate change in Canada.

2.3 The Practice and Science of Adaptation
Many examples of adaptation to climate can be found in Canada. Like many developed countries, Canada is relatively well adapted to its present climate. Normal climate is so universally present and so deeply ingrained in social and economic development that it is barely noticed and taken for granted. This is most obvious in agriculture where the choice of crops and mode of cultivation have been finely tailored over time to the prevailing climate. The same is true for forestry, fisheries, water resources, recreation and tourism, and garment industry which are obviously dependent on and sensitive to climate. The public health protection system has built-in safeguards against disease vectors including viruses, bacteria, insects, and parasites. Similarly the practices of insurance, credit, commodity futures and the like are all attuned to climate norms and known variability.

All present infrastructure embodies sunk costs of past adaptation to climate. Climate conditions, including climate variability and extreme events, are taken into account in all human built infrastructure. Climate is a factor in the design, construction and operation of civil engineering structures, systems and works of all description. Canadian laws impose instruments such as building codes, heating and ventilating standards, and municipal zoning by-laws in order to protect society from the effects of climate and adverse weather. In more traditional settings, the designs are not the result of formal analysis and regulation but have been developed over long periods of trial and error.

Despite all protective measures, storms and other extreme weather events cause damage. An occasional disaster demonstrates that improper attention to adaptation can have major and serious consequences. Adaptation to the extremes and the harshness of climate is not without cost and, while the cost cannot be specified with great accuracy, there is no doubt that it is considerable. Some estimates of these costs in Canada are summarized in Section 3.

The body of adaptation knowledge that is required for policy, management, and decision making is fragmented into disciplinary expertise and professional specialization. With the advent of climate change the standards and criteria applied in professional practice should be revised beyond the sector by sector adjustments. The challenge of this new science will be to capture the higher order effects on other sectors and geographical regions, including inter-provincial and international shifts in the distribution of natural resources and economic activities dependent on them.

The development of improved costs estimates for climate change impacts and adaptation requires the development of integrated assessment and adaptation science. A more integrated assessment should involve a coordinated adaptation strategy across different sectors and regions and across different policy domains. Creation of a new body of knowledge and practice that can be called ‘adaptation science’ is in order.

2.4  Social Adaptation Capacity

Many of the second and higher order impacts of climate change on society and economy can be reduced by adaptive responses. ‘Adaptation’ and ‘adaptive responses’ refer to all
actions that can be taken by individuals and society to offset or reduce the impacts of climate change, as follows:

- autonomous actions of individuals or enterprises, and
- policy driven responses by those concerned with planning and infrastructure development and operations.

As the adaptive capacity of a country or region decreases, the vulnerability to climate change increases, leading to greater costs associated with impacts. Successful adaptation will reduce the impacts associated with climate change, and will depend upon technological capability, institutional arrangements, availability of financing, and information exchange (Watson, et al. 1996). It is generally accepted that developed countries will be impacted less severely than developing countries, due in part to their greater adaptive capacity.

The public and private adaptation choices and decisions will have to be revised under conditions in which the climate is changing at an unprecedented rate and in ways that are not fully understood. A wealthy Canada, with a high availability of technical and organizational skills, will be able to offset at least some of the impacts of climate change, subject to the following conditions:

- Successful adaptation can only be achieved at a cost, which could be very large compared with the present costs of adaptation. The capacity to adapt varies amongst different sectors of the economy, different regions of the country, and different social groups within regions and communities (children, the aged infirm or handicapped, the poor and otherwise disadvantaged).
- Adaptation should take advantage of opportunities arising with climate change. The opportunities will not automatically produce economic benefits unless Canadians put an effort, initiative, and investment, the costs of which must also be considered.
- Significant residual impacts and costs will remain as a consequence of changes in means, variability, and extreme events associated with climate change. The costs of forest fires, floods, droughts and storms, and other less predictable elements of climate will remain significant and are likely to increase over present levels. The trends are already sharply upwards in some areas.
- There is likely to be some irreversible species loss, the disappearance of landscapes and loss of some of the natural heritage of Canada that it will not be possible to conserve.

3. Existing Estimates of the Costs of Impacts and Adaptation in Canada

Determining the costs of adaptation and residual impacts to climate change in Canada is difficult, as there is no sound basis for the estimation. Some progress has been made in identifying adaptation options in response to climate change, but there is little information on the actual costs of adaptation, or the residual costs which occur despite adaptive measures.
Smit (1993) provides a wide range of adaptations to climate variability and change that are available in Canada. These examples are drawn from different types of adaptations in response to past, present, and possible future climate conditions. An inventory based on a thorough literature review is also provided, although even this list "is not necessarily exhaustive of adaptive possibilities." Costs associated with these adaptation options are not included, and the task of estimating them across many sectors and geographical areas is daunting. Other methods must be sought in order to develop reasonable estimates of adaptation and residual costs. Before doing so, however, it is important to note that there is considerable agreement in the literature on at least three key issues:

- The costs of adaptations vary geographically, and from sector to sector. Further research is needed to improve our understanding of these differences in costs.
- Many measures promoted for adapting to climate change are small steps up from technologies that are currently available. This would suggest that associated costs could be small, especially if initiated early.
- Decision-makers may have a good, albeit imperfect, understanding of the broad range of adaptation options available in Canada, which address current climate. It is much more uncertain, however, if this knowledge is sufficient to enable successful adaptation to climate change by future Canadian society.

3.1 Estimates of Current Adaptation and Residual Impact Costs

Herbert and Burton (1994) estimated current costs of adaptation to climate. This is not the same as the costs of adaptation to climate change, but still is a useful starting point providing a benchmark for future costs. The estimated cost of adapting to current climate is over C$11.6 billion (Table 1.1), based on published material and expert opinion on current expenditures at the national level. Some of these figures may grossly underestimate present costs, as they were calculated from the early 1990s data. The cost of flood control, for example, is based on expenditures during the 1992-1993 fiscal year, predating many 'floods of the century' across Canada (southern Alberta in June 1995, Saguenay in July 1996, Red River in May 1997).

The survey results include data for 9 major sectors. For each sector estimates are given of total expenditures, the percentage attributable to climate adaptation, the cost of climate adaptation, and the possible trends under climate change. The costs of energy are subsumed under the appropriate sectors, while some adaptive costs were ignored (e.g. health care adaptations). These values need to be treated with caution. The authors expect that the aggregate adaptation costs will actually be higher than those presented. It is difficult to provide an aggregate measure how adaptation costs to current climate will change under future climate conditions, but estimates of trends for specific sectors can be made with a moderate degree of confidence. Adaptation costs associated with agriculture, forestry, water, emergency planning and weather information are expected to increase, while those associated with transportation and most notably household expenditure are expected to decrease.
### Table 1.1: Estimates of the Cost of Adaptation to Current Climate in Canada and Possible Trends Under Climate Change

<table>
<thead>
<tr>
<th>Sector/Activity</th>
<th>Total Cost (C$ million)</th>
<th>% Attributable to Climate Adaptation</th>
<th>Cost of Climate Adaptation (C$ million)</th>
<th>Possible Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport</td>
<td>7,368</td>
<td>100</td>
<td>1,657</td>
<td>decrease</td>
</tr>
<tr>
<td>Air</td>
<td>83.5</td>
<td>100</td>
<td>83.5</td>
<td>decrease</td>
</tr>
<tr>
<td>Marine</td>
<td>258.8</td>
<td>55</td>
<td>143.8</td>
<td>decrease</td>
</tr>
<tr>
<td>Rail</td>
<td>702.0</td>
<td>29</td>
<td>203.2</td>
<td>uncertain</td>
</tr>
<tr>
<td>Roads</td>
<td>6,323</td>
<td>19</td>
<td>1,227</td>
<td>decrease</td>
</tr>
<tr>
<td>Construction</td>
<td>2,000</td>
<td>100</td>
<td>2,000</td>
<td>increase</td>
</tr>
<tr>
<td>Agriculture</td>
<td>1,887</td>
<td>70</td>
<td>1,330</td>
<td>increase</td>
</tr>
<tr>
<td>Forestry</td>
<td>556</td>
<td>72</td>
<td>403</td>
<td>increase</td>
</tr>
<tr>
<td>Water</td>
<td>1,058</td>
<td>73</td>
<td>767.3</td>
<td>increase</td>
</tr>
<tr>
<td>Flood Control</td>
<td>4.7</td>
<td>80</td>
<td>3.8</td>
<td>increase</td>
</tr>
<tr>
<td>Household Expenditure</td>
<td>6,023</td>
<td>88</td>
<td>5,296</td>
<td>decrease</td>
</tr>
<tr>
<td>Emergency Planning</td>
<td>14.4</td>
<td>75</td>
<td>10.8</td>
<td>increase</td>
</tr>
<tr>
<td>Weather Information</td>
<td>189</td>
<td>100</td>
<td>189</td>
<td>increase</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>19,096</strong></td>
<td><strong>61</strong></td>
<td><strong>11,653</strong></td>
<td></td>
</tr>
</tbody>
</table>


Accounting for the residual costs of current damages remains incomplete. Despite the best adaptive intentions, residual costs of climate variability and extreme events can be extensive. Between 1984 and 1994, the Canadian insurance industry paid more than C$1 billion to compensate for losses sustained by major natural disasters. This figure appears to be on the rise (Brun 1997). The claims arose from thunderstorms, tornadoes, hail, windstorms and flooding, and concerned damage to homes, businesses and vehicles. The total costs to Canada, including the uninsured costs and damage to public property, is estimated at more than double the insurance costs. This figure does not include the costs of smaller events, suggesting that the true costs are much higher.

Prior to the Red River Flood of 1997 and the ice storm of 1998, the costliest single Canadian weather event during this decade was the Calgary hailstorm of 1991. It caused C$450 million in economic losses, with C$360 million sustained by the insurance industry. In July 1996, there was C$295 million insured costs for severe hailstorm damage in Calgary and Winnipeg. At the same time, excessive precipitation caused extensive damage in the Saguenay region, with the cost of the July 1996 flood estimated at C$1.1-1.5 billion, of which only C$350-400 million was insured costs. At the other extreme, lack of precipitation has also resulted in large costs. Extensive drought throughout the Prairies in 1988 resulted in C$1.4 billion in insurance payments and
government subsidies. These are only a few, albeit severe, examples of the residual costs associated with extreme events, and it is quite possible that such costs will increase under climate change.

While these figures may suggest that Canadians are not adequately prepared to deal with extreme events resulting in major disasters, the recent Red River flood offers both encouraging and disturbing insights. Although the final costs of the flood have yet to be determined, and are expected to be extensive, the costs could have been much higher if adaptive actions were not taken. Adaptations included a combination of past and emergency actions, most notably a floodway around Winnipeg constructed in 1963-1967, and the rapid construction of the 40 km long Brunkild Dike. The C$50 million invested in the floodway has no doubt paid itself off many times over, protecting the City of Winnipeg from no less than 3 major floods since its completion. On the other hand, despite the heroic efforts of many volunteers and the extensive building of protective infrastructure, the costs associated with the flood are large. More drastic measures, if not changing land use or location, may have to be considered. The adaptive responses may be necessary in other regions vulnerable to climate change, and rising sea level in particular. For example, an upgrading of existing dykes to protect the residents of Richmond, British Columbia, most of which lies below sea level, may cost hundreds of millions of dollars.

Careful and proactive planning, especially in infrastructure that has a relatively long lifespan is cost effective and sensible. Planners in the Town of Milton have recommended the spending of an additional C$7-10 million to enlarge a proposed water pipeline to accommodate expected water shortages under climate change. This amount represents an extra 10-15% of the base cost, yet is much cheaper than if changes were required later. The design of recently completed Northumberland Strait Bridge incorporated 1 m sea level rise due to the potential effect of global warming over the life of the project (100 years). The added cost of increasing the height of the bridge is small relative to both the total cost of the bridge, and the future costs that may be associated with countering the effects of a sea level rise.


Tol (1995) considered USA together with Canada under a doubling of the atmospheric concentration of carbon dioxide. By scaling US estimates to Canadian GDP, Rothman et al. (1998) estimated that an equilibrium 2.5°C warming and a 50 cm rise in sea level would entail a reduction of GDP in 1988 of 1.5% for the US and Canada, or C$8.3 billion (1986) in Canada alone (see Table 1.2).

Human mortality and morbidity make up nearly half of the total damages. Tol (1995) used a value for a statistical life of $250,000 US plus 175 times average income, yielding a value for a Canadian life of about $3.5 million US. Tol neglected impacts on forestry,
energy, water, air and water pollution, and many other potential impacts. Only coastal protection is clearly an adaptive measure among Tol’s categories. Dryland and wetland loss, and agriculture, reflect costs of adaptation plus residual damages.

<table>
<thead>
<tr>
<th>Category</th>
<th>Raw Data for US + Canada (From Tol (Tol 1995))</th>
<th>Percentage of Total Damages</th>
<th>Data for Canada assuming Equal Share of Damages between Sectors in Two Countries (Total GDP from CANSIM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal Defense</td>
<td>1.5 Billion SUS</td>
<td>2.0%</td>
<td>0.167</td>
</tr>
<tr>
<td>Dryland Loss</td>
<td>2.0 Billion SUS</td>
<td>2.7%</td>
<td>0.223</td>
</tr>
<tr>
<td>Wetland Loss</td>
<td>5.0 Billion SUS</td>
<td>6.7%</td>
<td>0.557</td>
</tr>
<tr>
<td>Species Loss</td>
<td>5.0 Billion SUS</td>
<td>6.7%</td>
<td>0.557</td>
</tr>
<tr>
<td>Agriculture</td>
<td>10.0 Billion SUS</td>
<td>13.4%</td>
<td>1.113</td>
</tr>
<tr>
<td>Human Amenity</td>
<td>12.0 Billion SUS</td>
<td>16.1%</td>
<td>1.336</td>
</tr>
<tr>
<td>Human Life</td>
<td>37.7 Billion SUS</td>
<td>50.6%</td>
<td>4.197</td>
</tr>
<tr>
<td>Migration</td>
<td>1.0 Billion SUS</td>
<td>1.3%</td>
<td>0.111</td>
</tr>
<tr>
<td>Natural Hazards</td>
<td>0.3 Billion SUS</td>
<td>0.4%</td>
<td>0.033</td>
</tr>
<tr>
<td>Impacts on the Insurance, Construction, Transport, and Energy Supply Sectors</td>
<td></td>
<td></td>
<td>neglected</td>
</tr>
<tr>
<td>Damage from Nontropical Storms, River Floods, Hot/Cold Spells, and Other Catastrophes</td>
<td></td>
<td></td>
<td>neglected</td>
</tr>
<tr>
<td>Other Ecosystem Losses</td>
<td></td>
<td></td>
<td>neglected</td>
</tr>
<tr>
<td>Other Human Impacts, including Morbidity, Physical Comfort, Political Stability, and Human Hardship</td>
<td></td>
<td></td>
<td>neglected</td>
</tr>
<tr>
<td>TOTAL</td>
<td>74.5 Billion SUS</td>
<td>100%</td>
<td>8.294</td>
</tr>
<tr>
<td>% of GDP</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Several categories, e.g. coastal defense, dryland and wetland loss, and agriculture, reflect costs of adaptation plus residual damages.

Categories considered in other studies not considered by Tol - forestry, energy, water, other sectors, air pollution, water pollution.

A statistical life, the "personal willingness to pay for risk reductions" (Pearce 1997, p.3), is assessed at $250,000 plus 175 times per capita income. (Tol 1996a)

Migration costs reflect the costs of incorporating immigrants into the social welfare infrastructure (Pearce, et al. 1996).
Tol (1996b) substantially revised both the total cost and the distribution among sectors. The loss of species has nearly quadrupled, whereas the estimate of mortality losses has dropped by nearly 75%. This illustrates how volatile the estimates are and how much they depend on evolving understanding of the impacts of climate change and the economic values applied.

3.3 Base Year 1990 Estimates by Mendelsohn et al.

Mendelsohn et al. (in preparation) have developed two sets of equations, based on studies in the US (except for the tourism sector). The equations relate market value to average temperature and precipitation levels, atmospheric concentrations of CO₂, length of coastline, land area, and other variables. The sectors considered are: agriculture, forestry, coastal resources, energy, water, and tourism. By varying the climatic parameters, the impacts of a changed climate can be calculated for each sector. The equations are based on a series of studies presented in Mendelsohn and Neumann (1999). Canada north of 65° latitude (well over half the land area of the three territories of Canada was omitted as it was assumed that economic activities there are limited.

A closer examination of the studies raises a number of questions about:
- optimistic assumptions about the benefits to agriculture and forestry from CO₂ fertilization,
- the lack of consideration of many of the costs of adaptation, and the fact that only those impacts that could be measured in the market for a subset of economic sectors were considered,
- the ability of estimating the costs using single, country-wide, annual average values for temperature and precipitation, and
- applying these results to countries with climate, biological, and socio-economic system characteristics outside the range over which the equations were estimated.

Even with the above caveats, it is still useful to look at the estimates that these equations provide for Canadian totals, if not for the specific sectoral impacts, costs, and benefits (Kloeppe 1997; Mendelsohn, et al. in preparation). For Canada, a warming of 2.5°C in 2060 is estimated to provide significant overall positive benefits, largely dominated by gains in agriculture and forestry.

4. Costing Methodology: Review and Assessment

4.1 The Monetary Evaluation of Adaptation Costs

As part of a ‘no regrets’ policy, the international climate change community has distinguished between mitigation of climate (e.g. efforts to reduce GHG emissions) and adaptation to climate. If we assume that climate change will occur, regardless of mitigation attempts, it seems natural to try to estimate the costs of adaptation. There will be a number of dimensions to the adaptation process and as many of these should be
costed so that policy makers become aware of the full magnitude of the effects of climate change.

Some of the dimensions of the adaptation process are easier to identify; firms may incur increasing or decreasing costs of production in particular sectors or particular regions depending on how climate change affects them. Besides the cost of production, both the private and the public sectors will have to make investments that make the private capital stock and the public infrastructure more resilient to extreme climate events. The general public will have to be more aware of the possibility of extreme events (floods in the spring, heat waves in the high summer, freezing rain or ice storms in the winter). Thus the general public too may incur costs of precautionary purchases.

In addition to the above, climate change will also affect physical, geochemical and biological processes. For example, climate change may affect the primary productivity of rivers, lakes and oceans; it may affect the nutrient cycle, and the hydrological cycle. The effects on biogeochemical processes will in turn have an effect on socio-economic processes. Most of these interactions (called nonlinear feedback effects) are not known, let alone try to estimate their magnitudes. Given these large unknowns, it is not possible to assign any probability of occurrence to these unknown effects. But assigning monetary values to these changes will “push economic valuation techniques to their limits, and quite possibly beyond” (Fankhauser 1995). In this section we review some key concepts of monetary valuation of adaptation costs.

In economics, in the market sphere, the concept of social value is synonymous with “market price”, provided the market is characterized by perfect competition. Even under perfect competition, the market cannot value public goods and it does not place a value on damage inflicted on public property (e.g. a factory that pollutes the atmosphere, a public property). This means that there is a problem of the valuation of market goods, and a problem of the valuation of non-market goods, i.e. goods of a public nature, such as forests, rivers, oceans, the ozone layer, etc. But before we consider the valuation of market and nonmarket goods, we discuss the issue of a common metric and the assumed substitutability a common metric implies.

The Implicit Assumptions about Substitutability in the Use of a Common Metric

Valuation generally implies the reduction of values to a common metric. In monetary valuation, this metric is dollars or some other form of currency. The use of a common metric contains within it the very significant assumption about the substitutability of very different items. If a dollar value can be placed on both a barrel of oil and a human life, does this mean that a sufficiently large number of barrels of oil can substitute for a human life? Can the extinction of a species be compensated for by placing the assets earned from their extinction in a bank and accruing interest on these assets? (Clark 1973)

Differences of opinion about substitutability underlie many of the debates about long-term development and environmental degradation. This issue has been extensively
discussed in the sustainable development literature and was briefly raised in the IPCC's Second Assessment Report (Pearce et al. 1996). Does "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" imply that future generations should inherit a world with as much of every resource as the present one? (World Commission on Environment and Development 1987) Or does it allow for greater quantities of one good to offset the irreversible loss of another?

Pearce et al. (1994) distinguish two broad approaches: weak sustainability and strong sustainability. Weak sustainability allows for the depletion of natural resources to be offset by future increases in human-produced capital or by the substitution of other goods. Advocates of weak sustainability presume the possibility for infinite substitution among goods. Thus, they are less concerned about the possibility of irreversible impacts and extinction, because they believe that future generations can be adequately compensated for any declines in the stocks of a natural resource by increases in the stock of other kinds of capital. This approach is inherent in any monetary-based valuation of climate change damage, which converts all of the various impacts to a single, monetary metric.

Proponents of strong sustainability insist that some environmental and social goods and services are irreplaceable and thus must be preserved. Strictly speaking, strong sustainability would preclude consuming any non-renewable natural resource, so in practice most advocates of strong sustainability allow for some limited trade-offs and substitutions among goods to be made. Their injunction against inflicting environmental damage stems both from a moral compunction against treating "probable improvements in the well-being of future generations ... as 'compensation' for harm knowingly inflicted upon them by present generations (Pearce, et al. 1996)" and from a belief that there are no adequate substitutes for many irreversible environmental impacts. Within this strong sustainability perspective, Pearce, et al. (1996) distinguish two broad standards for evaluating with the costs of climate change:

- The absolute standards approach insists that since the obligation to avoid harm is absolute, the costs of climate change impacts, like the costs of mitigation, are irrelevant.
- The safe minimum standards approach maintains that since many potential impacts are irreversible and the risks uncertain, harm should be avoided, subject to the constraint that avoiding harm (the cost of mitigation) does not impose unacceptable costs.

4.2 Valuation Methods in General

In considering monetary valuation, five different kinds of value have been identified: direct use values, indirect use values, option values, existence values, and other non-use values (see Figure 1.1). Ideally, all of these values would be represented in the price of a good or service sold in an open, competitive market, in which the external impacts of the production and use of the item have been taken into consideration. Under these
conditions, the price of a good would provide an accurate estimate of its economic value. In reality, these conditions are not met more often than they are - many items are not bought and sold, many markets are neither open nor competitive, and many externalities are not considered in the pricing of goods and services.

Economists have developed a variety of techniques for assigning economic values to goods and services for which there are no price-fixing markets. Economic value can be estimated through the price of proxy goods or services; oftentimes this is the cost of replacing the specific good or service of interest. Techniques exist to assess value via indirect markets, such as the travel cost method, which derives monetary estimates from data on costs of traveling to visit a particular recreational site or engage in a particular activity, and hedonic pricing methods, which attempt to decompose property and wage differentials into components that capture the use value of non-market goods such as air quality or mortality risk. Direct methods, such as contingent valuation, have also been developed in which artificial markets are created by directly asking people what they would pay for normally unpriced goods or be willing to accept as compensation for their removal (Freeman III 1993).

Figure 1.1: Categories of Economic Values Attributed to Environmental Assets (from Munasinghe, et al., 1996)
Though accepted by many within economics and other disciplines, these valuation techniques remain problematic in many situations. As noted above, many, if not most, existing markets are not free and do not consider many externalities. For price to accurately represent economic value requires that other, fairly strict requirements also be met. These include the existence of a world of rational agents, who are perfectly knowledgeable about the consequences of their actions and able, therefore, to act consistently in a way that maximizes their individual utility. Critics complain that human behavior hardly ever lives up to this assumption of economic rationality. People do not always understand the systematic effects of their behavior or the costs associated with various trade-offs. Other, non-economic values, such as family, community, and religion, are important as well, but economic valuation, as opposed to other, more qualitative forms of valuation elicitation, is not well suited to representing them. These other, non-economic considerations often make economic valuation very difficult, if not down right offensive to many.

This difficulty is reflected in the work that has been done to date on estimating the effects of climate change. Of the five types of economic value mentioned above and shown in Figure 1.1, the farther one moves away from direct use values, the less effort has been put into including these values in estimates of the costs of climate change. Some are even
categorically excluded, such as by the expert cited by Nordhaus (1994a) in a survey on the potential effects of climate change - "the existence value of species is irrelevant -- I don't care about ants except for drugs." In another example, the study by Mendelsohn and Neuman, which in many ways represents the state of the art, omits "non-market impacts, such as health effects, aesthetics, and some ecosystem impacts" These non-market impacts will likely include some of the most severe effects of future climate changes. An economic valuation that omits them will systematically underestimate the true costs of climate change, providing an incomplete and distorted basis for policy makers to address the threat of climate change.

4.3 Valuation of Market Goods

Market goods are valued on the basis of consumer demand, assuming that the market is perfect, or that producers cannot collude and fix the price nor exercise some form of market power. In the absence of market power, (independent) consumers determine the value. In general, it is the consumer's willingness to pay (WTP) which is the foundation of value in economics. However, it is also possible, under certain circumstances, to ask a consumer what she is willing to accept (WTA) to give up the right to use a good. Both WTP and WTA are legitimate measures of value, but are conceptually distinct. It is possible to determine a consumer’s willingness to pay for different price and quantity combinations, and then use this information to obtain the consumer’s “demand curve”. In general this demand curve is downward sloping. The area under the demand curve – up to any given price level – is called the consumer’s surplus (CS). In much of the environmental economics (and also cost-benefit analysis) literature, it is the CS which is the criterion of social value. In the literature, it has been shown that WTP < CS < WTA. Thus we have three measures of value which are different. The conditions under which the three are equal are very restrictive (see Chipman and Moore 1980; Dore 1998; 1996).

For market goods, the definition of cost follows easily: social cost is defined as the amount of consumer surplus foregone by a consumer. Thus one measure of the cost of climate change is the amount of CS foregone in order to adapt to climate change. We mentioned above that consumers will have to be more aware of extreme events and make precautionary purchases. This part of the adaptation cost can then be defined as the amount of CS foregone in undertaking these precautionary purchases.

Note that the theory discussed so far is valuation for an individual consumer. There remain many theoretical problems of aggregation across individuals. Aggregating over time produces further problems. These are discussed below.

4.4 Valuation of Non-Market Goods

There are many public goods and public ‘bads’, and services of environmental assets that do not have a market value. Examples of public goods are flood control measures and national defense. Noxious emissions are public bads. Examples of some services of environmental assets are the recreational benefits of lakes, rivers and beaches. Yet other
examples are the ecological services provided by forests such as: the regulation of the hydrological cycle, prevention of soil erosion, carbon sequestration, and the maintenance of biodiversity in the forests. The valuation of these types of non-market goods presents a challenge to economists.

The valuation of public goods is difficult because they have to be financed by taxation and consumers will have a tendency to understate their willingness to pay, on the assumption that the goods would be provided anyway. The valuation of recreational benefits can be achieved by various indirect methods, such as travel costs that consumers are willing to undertake in order to enjoy a recreational site, or hedonic price methods that attempt to break down a good into a number of characteristics which are assumed to be what the consumer desires. Another popular method is a survey method, called contingent valuation, that seeks to determine the underlying consumer’s willingness to pay for some recreational amenity. For example, a contingent valuation of the cleanup of the Hamilton harbour can be carried out; the survey would be subject to many biases, but in general a workable benchmark valuation of environmental recreational facilities can be found.

Unfortunately the same survey methods are inappropriate for finding the monetary value of the ecological services of the environment. Thus for example, survey methods cannot be used to place a value on forests for carbon sequestration, or for regulating the hydrological cycle (Dore 1997). For these ecological services, an alternative is to ask the question: what would society lose if the forests were not there? This approach is called social opportunity costs. In such a perspective it is possible to view forests, rivers, oceans, etc. as part of society’s natural capital. If the forests and the oceans are a carbon sink, they permit the production of goods by absorbing some or all of the carbon emissions. Thus carbon sinks are natural capital; we can think of “employing” this natural capital jointly in burning fossil-fuels. Thus carbon sinks have opportunity costs.

Most valuations of ecological services can be considered *seriatim*, as a series of “thought experiments”, to aid in valuing various environmental services. But it would be misleading to add up a series of thought experiments to produce an aggregate monetary value of the biosphere. This is precisely what Costanza (1997) did when he valued the world biosphere at 1.8 times the world GNP.

However, thought experiments to value a forest, a lake, or a beach might be good mental aids, but all results of thought experiments are highly sensitive to assumptions made in order to compute a particular value of an environmental asset. The problem is even more difficult when attempting to apply this array of concepts to measuring the costs of adaptation to climate change.

4.5 The Policy Context

The policy context in which global climate change is being debated demands monetary estimates of the costs of future climate change impacts. The inherent objective is to determine what the effects will be on human well being. There are large uncertainties
surrounding the rate, magnitude, and regional variation of projected climate changes, their impacts on human and natural systems, and the effectiveness of future adaptations. Perhaps as important as these uncertainties are the difficulties in translating these into costs and the fact that value-judgments are necessarily built into any damage assessment measure. As Banuri et al. (1996) emphasize, "it needs to be recognized that attempts to quantify the costs associated with climate change involve inherently difficult and contentious value judgments, and different assumptions may greatly alter the resulting conclusions." And as Grubb (1995) warns, "(t)here is the danger that economic evaluations... Enshrine in apparent objectivity the current value system of the practitioner."

Although other methods do exist and monetary valuation is highly contentious, even within economics (Vatt and Bromley 1995), it is a standard way used to represent changes in welfare using WTP, or some approximation to it. To perform such a valuation exercise is a daunting task. Climate change will affect a dizzying array of physical, geochemical, biological, and socio-economic processes.

So what is an appropriate costing method for the adaptation costs of climate change? That will depend on which costs are identified as being due to climate change. We have mentioned at least four kinds of costs that may be associated with climate change: (1) increasing (or decreasing) costs of production for particular sectors or regions, (2) costs of adapting the private capital stock and the public infrastructure to make it more resilient to extreme climate events, (3) the costs of emergency preparedness incurred to save lives, including health costs and property repair costs, and (4) the precautionary purchases of the general population. For each of these, the appropriate cost concept would be obvious. For increased costs of market goods, the appropriate cost is the consumer surplus foregone; for increased resilience of the capital stock, it is the cost of investment which has an opportunity cost - what the investment would have earned in its best alternative use; for emergency preparedness it is the extra government expenditure required to cope with the emergency. Finally for the precautionary purchases of the general public, it is the CS foregone. Focussing on these four components ignores a whole host of costs associated with the nonlinear feedback interactions between biogeochemical processes and socio-economic processes; as stated above, many of these interactions are not known (Tol 1996a).

4.6 Aggregation Across Individuals, Sectors, and Regions.

As consumer willingness to pay and consumer surplus are individual concepts, the monetary valuation that is obtained will be a function of both the culture and level of income that consumer enjoys. Hence the poorer the consumer, the lower the valuation. Thus there is a clear income bias (Banuri, et al. 1996). This problem was central to the controversy over the IPCC’s treatment of the value of a statistical life, which is higher in the developed countries than in the developing countries (Pearce 1996; Pearce et al. 1996). Secondly aggregating this biased estimate of value across individuals requires some set of predetermined weights. The weighted measure will again reflect the income
bias so those poorer regions would be underrepresented in the aggregate measure.
Fankhauser, Tol, and Pearce (1996) have shown that any measure of climate change costs
will be highly sensitive to the assumed equity weights, and that uniform equity weighting
yields the lowest aggregate estimate; the measure could vary by a factor of 5 depending
on the weights chosen.

A fundamental concern with economic valuation is that most of the techniques used are
biased against persons with low income. The price of market goods are functions of
effective demand, i.e. the ability of a person to make their demand felt within the market.
For non-market commodities, although both willingness to pay and willingness to accept
compensation are theoretically valid measures, it is generally the former that is used in
valuation.

Geographic Specificity of Estimates

Because economic valuation of climate change impacts is so difficult, it has only been
attempted for a limited set of goods and services and a limited set of values in a limited
number of areas. In particular, most of the work has focused on the United States. Many
of the estimates for other regions are based upon transferring U.S. based estimates to
these very different locales. However, biological, societal, and economic structures, as
well as cultures and values, differ widely within and between countries. Also, for a
number of countries, the temperature and precipitation values may be outside the range
over which the original estimates were made, making extrapolations tenuous.

Missing Interactions

Finally, by estimating economic values at a small scale and then aggregating these,
important interactions and inter-dependencies are lost. In examining the higher-order
effects of climate change, Tol (1996a) notes that the "cost of impacts together is larger
than the sum of the individual impacts." A prime example of this is seen in how
agriculture has generally been dealt with in studies evaluating the effect of climate
change. Since agriculture comprises only 1-2% of GDP in developed countries, such as
Canada, a complete destruction of Canadian agriculture would only result in a 1-2% GDP
loss in standard measures of the effects of climate change. This ignores, however, the
extreme dependence of other sectors of Canadian society on agriculture. (Howarth and
Monahan (1992) illustrate the difference that considering these dependencies can have
on estimating values.)

4.7 Aggregation Across Time

Changing Values

Estimates of the costs of future climate change are sensitive to assumptions about the
kind of future society that will be the recipients of the future climate. How vulnerable
will these societies be? How much and how successfully will they be able to adapt?
Perhaps more importantly, how will their values and preferences differ from those of members of the present society.

Most studies use present monetary values to calculate the costs of future climate change impacts and adaptations. These express present-day cultural practices and preferences, not future ones. Because of the trans-generational nature of climate change, this introduces a critical uncertainty in estimating the costs of climate change. Tol (1994) shows, by considering the increased willingness to pay for environmental goods that is assumed to come with projected future increases in income, the costs of climate change may be significantly higher than common estimates.

Some adjustments can account for the rising relative preference of future generations for greater quantities of presently valued environmental goods and services, but they do not take into account the possibility that future generations may value the environment differently than we do. Take the example of coastal salt marshes, which are now threatened by rising sea-level. Largely ignored today, except for their amenity value and the provision of wetland habitat, a century ago, diked salt marshes were among of the most valuable agricultural lands in Canada, providing the hay that fueled horse-drawn society. An 1897 estimate of the economic costs of inundating Canada’s salt marshes would have put a much higher price on these impacts than a similar estimate today. Similarly, eastern hardwoods, which were regarded by the professional foresters a century ago as weeds, are now valuable commodities harvested for biomass (Irland 1996).

Bias Against the Future - Discounting

Based upon the assumptions that people are impatient and would rather receive a dollar today than tomorrow (the pure rate of time preference) and that an extra dollar is worth less to a richer person, which we are all assumed to be in the future, than a poorer person (the declining marginal utility of income), economists often apply a discount rate to future values in order to aggregate these across time. This is based on the idea of a single long-lived agent able to make rational trade-offs between present and future benefits. This assumption does not hold for the long time involved in climate change, which involves decisions about the inter-generation allocation of costs and benefits, however. On this basis a number of authors (Broome 1992; Howarth and Norgaard 1995; Arrow et al. 1996; Khanna and Chapman 1996) have argued that discounting is inappropriate to the evaluation of climate change damage.

The debate about discounting is important because calculations of the costs of climate change (and thus the policy recommendation that flow from them) are extremely sensitive to the choice of discount rate. For example, at a 7% discount rate (as is commonly used in short-horizon project analysis), damages of $1 Billion 50 years hence have a present value of only $33.9 million; the same damages 200 years hence have a present value of only $1300.
4.8 Evaluating a Changing versus a Changed Climate

To minimize the effect of the compounding uncertainties that would be introduced by trying to project economic and social changes, most estimates of the costs of climate change are based upon a present day benchmark. That is, they ask what the difference in GDP would be between the present economy under the present climate versus the present economy under a scenario of a different climate. By holding constant all social and economic variables, these estimates attempt to tease out the specific differences that a changed climate would make.

By simply imposing a changed climate onto the present economy, these estimates effectively ignore the costs of a changing climate, particularly the transaction costs that would be required to adapt to the new changed climate. The costs of many adaptations, therefore, are not counted, and in many cases the ability to adapt, which has been shown to significantly reduce climate change impacts (Fankhauser and Tol 1996), may be greatly exaggerated. For certain sectors, particularly agriculture, these costs, which are very dependent upon the rate of change, can swamp the equilibrium costs of the changed climate. Tol (1996a) posits a more complete theoretical model and empirically shows that assumptions about rates of climate change and the speed of damage restoration and adaptation have a significant effect on estimates of the effects of climate change.

4.9 Uncertainty

Before considering uncertainty in general, it was noted above (Section 2) that we take the climate for granted. We do not have a clear idea of the costs or benefits that climate bequeaths to human societies. If we knew the costs (or benefits) of the current climate, then we might try and evaluating the costs (or benefits) of changes in the climate. But in order to do that we would have to recognize that the climate is the result of the interaction of the oceans, the hydrological cycle, forests, and solar energy. Is it possible to put a monetary value on the sun? Trying to unpack the climate box in order to put a monetary value on it could lead to absurdities. Hence it might be extremely difficult to try to place a value on the current climate, let alone place a value on changes in it.

Uncertainties in How Climate Will Change

To deal with many of the uncertainties in estimating the effects of climate change, a number of simplifying assumptions are commonly made. As noted previously, estimates are often made of the impact of a changed climate on present-day society. Secondly, although climate change is a continuous process, with no real equilibrium state, most studies consider the impacts of a changed climate that has reached a state of equilibrium. Thirdly, even though the absence of efforts to reduce the emissions of greenhouse gases is
likely to lead to atmospheric concentrations of CO₂ exceeding pre-industrial levels several times over, almost all studies of climate change impacts and adaptation to date have based their estimates assuming only a doubling. This is, in many respects, due to the early General Circulation Model (GCM) experiments, which have focused on an equivalent doubling of atmospheric CO₂ concentrations. Finally, although the possibility for surprise and catastrophic impacts is widely acknowledged, most studies have not considered these explicitly; rather they have assumed a smooth transition to a new climate.

Each of these assumptions is likely to have a downward bias on estimates of the effects of a changing climate. We have already noted that focusing on a changed climate ignores many of the transient costs associated with a changing climate. This bias is likely to be more significant if the changes do not occur smoothly. By limiting the analysis to the case of a doubling of CO₂, the effects of larger changes in climate are neglected. Cline (1992), among others, has noted that these effects are likely to increase more than proportionally with changes in climate. Of course, the importance of these changes, since they are not likely to happen for some, depends critically on how researchers deal with the issue of discounting as noted above.

Presentation of Uncertainty

It has been noted earlier that most of the work done on impacts and adaptation have used global mean temperature change as a proxy for climate change and they assume a gradual change to a new equilibrium climate. Although the possibility for surprises and catastrophic impacts is widely acknowledged and some studies have considered issues of uncertainty related to climate changes and human responses, the presentation of the costs has focused on 'best guesses' of the most likely scenario.

Figure 1.2 illustrates the problem with this approach. Many of the uncertainties related to climate change have large right hand tails, i.e. the range of uncertainty is not symmetric, but rather there are relatively more possibilities for low probability-high impact occurrences. In such a situation, the impacts associated with the best guess, i.e. the occurrence with the highest probability, can be significantly lower than a weighted average of impacts, each weighted by their probability of occurrence. In effect, the best guess downplays the risk of very costly scenarios. Furthermore, a policy decision based upon the best guess would imply a society that likes to take risks, because the risk premium, i.e. the difference between the best guess and the expected value, is negative. This runs counter to most public policy choices, where a positive risk premium is paid, reflecting the risk adverse nature of society.

Another way in which the presentation of uncertainty is problematic is that when different studies are compared only the totals are usually considered. Because many of these studies consist of aggregations of sectoral estimates, each of which are independent, it would be more appropriate to consider the range of estimates for each sector prior to
calculating the aggregate. Doing so will broaden the range of uncertainty and more clearly point out the possibility of much higher damages (Demeritt and Rothman 1998).

To sum up this section: the methodology of costing is extremely limited to the task at hand. We can place a value on market produced goods, and we may try to extend these methods to public property such as beaches and national parks. We may even carry out thought experiments on the monetary value of some ecosystem services. But trying to aggregate these values presents tremendous difficulties. We do not know the monetary value that the current climate makes to human wellbeing; we just take climate for granted. Trying to put a monetary value on changes in it is even more fraught with difficulties.

Figure 1.2: Damage Distribution, Catastrophic Events, and Best Guess Estimates [from Fankhauser (1995)]

5. Improving Costing and Interim Steps

The information available on the costs of climate change impacts and potential adaptation in Canada is very limited and unreliable. Until such time as these estimates can be improved Canadian policy and decision making will be flying blind. This is an important gap in knowledge and steps should be taken to improve the estimation methodology and provide better information to the policy process.
We recommend three complimentary directions to improve upon this situation. Steps should be taken to improve on the estimates using the most promising approaches. This entails improvement of methodology as well as the more intensive use of existing methodology. Many of the difficulties that hinder progress in this direction are not susceptible to easy or short term remedy, and some of the uncertainties are likely to remain no matter how much more work is done. They are simply inherent in the situation. Therefore we suggest two interim steps that can be taken to improve information for the policy process. The combination of greater efforts to improve cost estimates and the interim measures we propose will still not provide a fully satisfactory basis for policy making. We therefore also suggest some additional and alternative approaches.

5.1 Better Estimates

The four approaches below offer possibilities to explore impact and adaptation costs. They might best be used in combination, for example in an integrated assessment of climate change in a region of Canada.

1. Historical and Spatial Analogues: Impact and Adaptation Costs Experienced Elsewhere and at Other Times

Not much is known about society’s transition to a new climate and less vulnerable society, yet this is the prominent aspect of costing the responses to climate change. An alternative approach would analyse social adaptations to climate rather than climate change (Pielke 1998). Besides climate and weather, societies have been continually adapting to natural and man-induced change and hazards. Analysis of future climate change impacts and adaptation in Canada will assume scenarios of future social responses, which might have common elements with those observable in adaptations at other times and in other places.

Studies of comparable historical situations (historical analogies), or studies of geographical regions in climates comparable to future Canada (spatial analogies) can identify transferable factors that may be relevant to projections of adaptation behaviour of Canadians under climate change. Several authors have examined analogies in the climate change context (Lamb 1982; Glantz 1988; Glantz 1996). Consequences of events caused by extreme weather in Canada are presented by Phillips and McKay (1981) and Etkin (1998). On the basis of recent experiences of weather extremes in various provinces, Burton et al. (1999) examine some of the factors that determine how Canadian society could develop to be more adapted to extreme weather events. Historical and spatial analogies of other natural and man-made hazards and of their impacts on societies might also be insightful.
2. Cost Estimates Based on Input Output Models

The measurement of adaptation costs depends on how the costs are defined. The definition needs to be operational and appropriate to the problem on hand. Suppose that we define the adaptation and residual costs to be (a) changes in production costs due to climate change, (b) changes in capital costs for making the private capital stock and public infrastructure more resilient to extreme climate events, (c) increased public expenditures needed to meet the emergencies as a result of extreme climate events, and (d) increased consumer (precautionary) expenditures necessary to cope with extreme climate events. In the case where a country has good time series data in the form of input output tables, all the above-mentioned adaptation costs can be estimated using econometric time series methods, if it is assumed that climate change will occur slowly and that therefore the production and consumption structure of the economy will also change slowly. This is a very plausible assumption.

The econometric time series can then be used to compute the upper and lower confidence limits of the four estimated cost parameters. The confidence limits may be the 95 percent confidence limits or they may be 99 percent confidence limits. These limits will then indicate the expected range of the costs, based on the time series analysis; the time series approach would be a valid method because the structure of the economy will change slowly as climate change will occur slowly, i.e. without any sudden and catastrophic changes in the economy. In the case where outside evidence (e.g. the Canada Country Study) suggests that the costs will increase, the difference between the upper confidence limit and the fitted regression estimate can be a good measure of the particular adaptation cost.

An example will help illustrate the method. Suppose that data on agricultural inputs is collected from the Input output table for a particular region, say Ontario. We can fit a statistical time series model that is statistically significant, and compute the 95 percent confidence limits for the inputs. Assume that for Ontario, the outside evidence (from the Canada Country study) indicates that as a result of climate change there will be higher precipitation, which will reduce the need for some inputs, such as fertilizer and water. Then we can take the difference between the fitted estimate and the lower 95 percent confidence limit to find the expected reduction in the adaptation costs of this particular sector for this particular region. The approach can be applied on a sectoral basis to each of the four cost components, provided that Input output tables exist. For Canada there is an excellent annual time series of input-output data from 1965 to 1995. In principle the input-output data can be disaggregated by province and the analysis carried out.

The advantage of this method is that it uses existing data. Furthermore, it should be relatively easy to disaggregate the data for individual provinces. Another advantage of the method is that input-output data are already reconciled with national income and GDP data, and therefore would easy to estimate the cost impacts. The main theoretical weakness of the input-output method is that it is a linear method, which assumes fixed
input coefficients. This means that an input-output table ignores any nonlinear interactions among firms. The main practical limitation of the method is that the analyst is limited to the sectors chosen by those who compile the input-output tables (i.e. Statistics Canada). Finally, if the compilers used poor sampling techniques on developing the input-output table, then the quality of the cost estimates will depend on the quality of original data itself. But of course that applies to all economic data.

3. Valuation of Ecosystem Services

Natural habitats and biodiversity will be significantly affected by climate change. The evaluation of climate change impacts can be substantially enhanced, if the monetiseable part of natural resource changes could be more accurately represented. Monetary valuations of ecosystem services to society have been attempted for natural capital outside of Canada (Costanza et al. 1997; Farber 1996). Canadian habitats have unique characteristics and are richly diversified, which warrants monetisation locally for habitats known to be affected by climate change. International monetary values of ecosystem services are either inaccurate or do not apply to Canada (Bein 1997).

4. Integrated Assessment

Integrated assessment (IA) evaluates adaptive measures and impacts of climate change in a systemic context (Cohen and Tol 1998). IA studies attempt to transcend sector, disciplinary, cultural, and jurisdictional barriers, promoting collaboration and shareholding in the climate change issues. IA studies involve scientists with local stakeholders, policy and decision-makers, and the public. The participants become familiar with potential consequences of climate change in their own jurisdiction and think about responses in local terms. Integrated assessment can unify issues of mitigation and adaptation. The IA process draws both on the local knowledge and values, and on the scientific research results, posing the climate change problem to those who ultimately will be adapting to impacts.

Costing can be applied to data generated in a local IA study of future climate and social scenarios. Such studies can produce costing information of high relevance to policy making. The data is more comprehensive, accurate and representative, as local climate change impacts and adaptation are considered together with natural and socio-economic changes taking place at the same time. Broad context of IA studies facilitates connecting sustainable development with climate change, a missing link in other approaches (Cohen et al. 1998).

Canada has performed an IA using a scientist-stakeholder collaborative approach in the Mackenzie Basin Impact Study, but costing of impacts and adaptation options has not been incorporated into any IA studies in Canada yet. A current example is the assessment taking place across regions and sectors of the United States (Melillo 1999; Parson 1999). The study will aggregate the results into a national whole. In Canada, IA of climate
change, and the costing component of it, could be incorporated into initiatives such as Georgia Basin Futures Project and Toronto-Niagara Region Study.

Integrated assessment models (IAMs) differ from IA studies. They tend to be reductionist, simplify the real world to facilitate numerical analysis, and introduce limiting assumptions of the underlying components. IAMs incorporate costing data and models with their drawbacks. By contrast, IA studies are free to use or not to use sector and other mathematical models as they see fit to accomplish project objectives.

5.2 Interim Steps

Much time is spent thinking about and trying to assess future costs of climate change impacts and adaptation while little is known quantitatively about present day costs. It is clear that some adaptation will be needed in virtually all sectors of the Canadian economy and all regions. While the level and speed of adaptation actually implemented cannot be known in advance, it makes good precautionary sense to prepare now for adaptation and to ensure that adaptive capacity exists and is strengthened where necessary.

1. Costs of Present Climate and Adaptations.

There are no estimates of the present cost of climate conditions and variability in Canada. Even with respect to extreme events such as floods, droughts, hail, high winds and the like, the best estimates available are based upon insurance claims which are not consistent across the country; do not include flood losses from overland flow; and do not include economic (non-insured) damages from any natural hazards. The data that are available are suggestive of a recent rapid rise in losses from extreme weather related events. Much better data is needed if the policy process is to be well informed about the costs of current weather, its variability and extremes. To collect such data in a systematic fashion falls within the responsibility of the Federal Government and for which there exists the necessary technical expertise in Statistics Canada. Until there are reliable time series of the insured and economic costs of weather variability and change available there is no way of making a proper evaluation of the estimates of future damage from climate change and the adaptation costs. Some baseline estimates are needed however rough. A more rigorously designed data collection program on present day climate costs is probably justified considering the issues at stake.

Unlike estimates of future damages and adaptation costs, which have to be based upon uncertain scenarios of future climatic and socio-economic conditions, data on present impact and adaptation costs are a matter of empirical evidence that can be collected and verified at the time of occurrence. In the past such information was not so important to policy issues, and it has been safe and adequate to rely on largely anecdotal and unsystematic evidence. The fact that claims under the Federal Disaster Assistance Act are now climbing sharply gives further impetus for the development of a standardized method of climate damage data collection, and for estimates of adaptation costs. A task force of statisticians, economists and climate change experts could be established to
suggest designs for such an information gathering process, and to propose how this might be done in a cost effective manner.

This is not only a Canadian issue. Climate cost data will sooner or later become an important requirement in international negotiations under the UN Framework Convention on Climate Change. This is an issue that could be taken up by Canada within the Intergovernmental Panel on Climate Change and the World Meteorological Organization.

2. Adaptation Capacity

Little is known about the adaptation capacity of different sectors of the Canadian economy and different regions of Canada. It is clear that vulnerability to climate variability and change are not evenly distributed across Canada. Research is needed therefore to assess climate change impacts in terms of the capacity of regions and sectors to adapt. The results of such an analysis are by no means obvious. For example, it is often stated in impact studies that agriculture will be highly affected by climate change because it is clearly such a weather dependent activity. On the other hand it is also know that Canadian agriculture is highly adaptive and that the farming industry is continually in a state of responding to changing market conditions, new technology, new cultivars, and new pest and plant disease infestations. Further, significant agricultural investment is short term because the turnover of crops is rapid compared with the longer production cycle in other industries. The adaptive capacity of Canadian agriculture is not likely to be the same for all regions and all types of farming. Research into the level and variability of adaptive capacity could help to fill an important knowledge gap. In Canada, buildings and other capital infrastructure seem to be well designed to resist weather and climate variability and extremes, but it is also true that the design of infrastructure is based upon climate normals which are now changing more rapidly than before. It is important therefore to start to estimate the potential costs of new design standards as well as the costs of retrofitting.

Where the costs of adaptation lie, and where they will be most significant remains an open question that should be examined now. This research should also be accompanied by assessment of adaptive capacity.

5.3 Alternatives to Costing

1. Risk Assessment

Climate change is such an indeterminate phenomenon that single point estimates of impacts and corresponding adaptation costs have little meaning. It is suggested that a risk assessment approach be adopted in which a range of possible outcomes is identified and associated with practicable and a probability estimate of its occurrence. In fact such a science-based risk management framework for climate change in Canada has been developed in preliminary form (Bruce et al. 1999). This requires further elaboration including a more detailed analysis of climate change risks within the framework.
proposed. While this will not by itself provide new costs estimates it will help to better identify where the crucial costs are likely to lie.

2. Multi-objective Decision Analysis

The multi-attribute utility (MAU) approach is an evaluation method for decision problems with multiple objectives and uncertainties (Keeney and Raiffa 1976). The method operates on the concept of ‘utility’ -- a common metric with which value judgements of the decision makers are assessed for all criteria; economic, physical and qualitative.

The MAU approach is difficult to implement when there are many and diverse decision criteria, many decision makers, and when sequential decisions are added to the problem. Scarcity of objective probabilities, controversy of subjective probabilities from numerous decision makers and stakeholders, and the difficulty of extracting utility values from decision makers preclude the MAU approach from evaluation of climate change problems (Arrow et al. 1996). The problem of adaptation to climate change impacts, possibly including mitigation, could still be structured to fit MAU framework. Decision analytical representation, perhaps applied within a current Canadian IA study, could lead to a better cognition of the complex information content.

3. Valuation Constrained by Sustainability

Valuation of choices based on the sustainability philosophy deals with non-market impacts of climate change. Some people consider that putting monetary value on natural assets sends signals to the market that encourage substitution with man-made assets and depletion. An ‘absolute standards’ approach was conceptualised to prevent this. The approach assumes that decision makers are obliged to avoid future harm because the current generation has a duty to avoid harming other species and future generations. An absolute restraint put on human activities so as to prevent a loss of natural goods and services in the future is not a practical solution. Society needs to make day-to-date decisions which are responsive to near-term economic needs and human existence is impossible without consequences for the biosphere.

‘Safe minimum standards’ approach allows the current generation to use resources to a limit imposed by leaving future generations as well off as itself. The approach is difficult to operationalize.

References


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