HOW RELIABLE ARE CLIMATE CHANGE PROJECTIONS – A STATISTICIAN'S PERSPECTIVE

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1. Introduction

Climate change is one of the most important, if not the most important, global policy issues facing us today. Quite rightly it is the subject of considerable scientific work and much policy debate. I am going to be critical of some aspects of the work of the International Panel for Climate Change (IPCC) in my comments. Please don't interpret that as me being one of those climate change sceptics. I am not. I do believe it is an issue that our societies must address. But the policy interventions should be based on the best possible evidence and I believe the IPCC's work on climate change projections falls short of that standard. Furthermore, some of the commentary based on their work exaggerates their findings.

Having made that critical statement I would like to recognise the strength of much of IPCC's work. It is wonderful that it has been possible to being together so many experts to try to develop a collective view on a very important topic. It is one of the most outstanding examples of international collaboration. Furthermore their work has had a substantial influence on national and international policy. And the outputs of the work of the IPCC will provide an excellent base for much more scientific work. I should also comment them on the transparency of their work even though it makes it easier to criticise.

Unfortunately the experts gathered together for the IPCC's work did not include statistical experts. This has resulted in some potentially serious flaws in the statistical work of the IPCC which I will describe shortly. These flaws will tend to exaggerate the extent of future climate change. These upward biases are not sufficient to suggest there is not really a climate change problem but they may be sufficiently important to influence the adaptation policies of individual countries. If unnecessary policies are introduced, public funding could be wasted possibly at the expense of additional funding for items such as health, education or other environmental issues.

You could think of policy interventions on climate change as a dichotomy - those that are aimed at reducing the growth in greenhouse gas emissions and those aimed at adapting to the impact of future climate change.

Starting with the first issue, in most countries, there is general agreement that the level of greenhouse gas emissions has to be reduced with much debate on appropriate policy interventions. The work of the IPCC has been a major influence. Their work has shown without doubt there has been global warming, increases in sea levels, etc. They have also shown fairly convincingly that human activity is a major contributor to the increase in greenhouse gases. I have no quibble with this work. My concern is with the projections of possible future climate change. Whilst, in my view, there may be upward biases in their estimates of future climate change, they are not sufficient to suggest that climate change should not be addressed with some urgency. But these biases may be important for determining appropriate responses or adaptation to future climate change. For example, the policy response will be quite different if the increase over the rest of this century is likely to be 2 degrees rather than 6 degrees. Governments and others deserve the best possible evidence base - there is a lot at stake.

And it is not just governments that might be impacted. One private sector example is insurance. Insurance companies are likely to use IPCC projections to help them assess risks. If the risks are judged to be higher than what they might be, those taking out insurance are likely to pay too high a premium.

The public will also be disadvantaged if public spending is sub-optimal and strong needs, such as those in health, education, water and waste management for example, are not met by the public purse because funds are diverted to climate change adaptation policies that may be unnecessary.

Of course I recognise there is considerable uncertainty in the predictions. And that current and future policy responses, or lack of responses, may lead to decreases or increases in greenhouse gas emissions compared with current scenarios. There will be other external factors at play which also impact on the future. The rapid decline in population growth over the last decade or so was not predicted by most when I was doing university studies some 40 years ago!

You might ask what are my credentials for making the criticisms I am about to make. First, I was the Head of the Australian Bureau of Statistics for nearly 7 years. Second, I am a past President of the International Statistical Institute, the peak global body for statisticians. Third, I am Chairman of the Global Executive Board of the International Comparison Program. This Program, which is hosted by the World Bank, is responsible for providing up-to-date estimates of purchasing power parities (reference period 2005-2006) and it is the non-use of power purchasing power parities which will be one of my criticisms. Fourth, I have been a member of the Australian State of the Environment Committee since 1998. This Committee is charged with providing an independent report on the State of the Environment to the Australian Government.

I have recently retired as Australian Statistician so my views should not be interpreted as representing those of the Australian Government.

2. The Conclusions of the IPCC

These are not always well understood. Many commentators have a tendency to exaggerate the likely impact, using the upper limit of the IPCC projections, and causing some public alarm.

According to the IPCC's Summary for Policy Makers, temperatures are expected to increase by about 0.2 degrees per decade over the next two decades for a range of scenarios. That is, temperatures are expected to increase by nearly 0.5 degrees by 2030.

A lot of the projected increase is due to past actions and an increase of about 0.3 degrees would be expected even if greenhouse gas concentrations could be maintained at 2000 levels.

Beyond the next two decades, different outcomes result from the different scenario groups. The 'worst case' A1FI scenarios projects temperature increases of 2.4 to 6.4 degrees (with a best estimate of 4.0 degrees) by the end of the century. Sea levels are projected to increase by 0.26 to 0.59 metres over the same period. Their 'best case' B1 scenario projects temperature increases of 1.1 to 2.9 degrees (with a best estimate of 1.8 degrees) by the end of the century. Sea levels are projected to increase by 0.18 to 0.38 metres. Recent public announcements suggest many countries are trying to reduce the level of their greenhouse gas emissions. The speed at which these changes are made is also important because the accumulative affects of greenhouse gas emissions are very important.

Climate Change Scenarios

The scenarios are based around six basic storylines.

A1 – This describes a future world of very rapid economic growth, global population that peaks in mid century and declines thereafter, and the rapid introduction of new and efficient technologies. Economic convergence among the regions is assumed with a substantial reduction in regional differences in per capita income. There are three subgroups within the A1 family distinguished by the direction of their technological emphasis.

A1FI – fossil intensive energy sources

A1T – non-fossil energy sources

A1B – balanced across all sources

A2 – This describes a very heterogeneous world with emphasis on self reliance and preservation of local identities. Continually increasing population is expected. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented than in other storylines.

B1 – Similar to A1 but with a rapid change in economic structures toward a service and information economy with reductions in material intensity and the introduction of clean and resource efficient technologies.

B2 – This storyline has an emphasis on local solutions to economic, social and environmental sustainability. Population continues to increase but at a slower rate than A2. Intermediate levels of economic development are assumed with less rapid and more diverse technological change than in the A1 and B1 storylines.

Part of my argument will be that the statistical biases are such that some scenarios with poorer outcomes are much less likely than those with better outcomes. The scenarios should not be treated as equally likely. This impacts the longer term projections only. Over the next 20 years projected increases are much the same for all scenarios. It is over the longer term that major differences from the scenarios emerge.

If policy interventions lead to even more optimistic scenarios than those described in the box above, projected outcomes would be even better over the longer term. I will not comment on this aspect as it is beyond my brief. But my comments will suggest that the B1 scenario family may be most likely but with a lower level of economic convergence.

3. What are my concerns?

They are summarised below and expanded in the following paragraphs.

1. The first criticism is the so called Castles/Henderson criticism. Because exchange rates rather than purchasing power parities are used to compare the size of economies in the climate change models, the economic growth of developing countries (where exchange rates tend to be undervalued compared with purchasing power parities) has an upward bias where economic convergence is assumed as is the case in many of the scenarios. (see next point)

2. The second criticism is the economic convergence assumption in many of the scenarios. For example, in the A1 scenario average incomes are predicted to converge by nearly 2% per annum. For the A2 scenario the convergence is a much more realistic 0.5% per annum. (For the B1 and B2 is assumed convergence is somewhat higher than that assumed for the A2 scenario but a lot lower than for A1.) While there is likely to be a move in this direction, the most likely outcome is that most of the developing countries of today will still be behind the more developed countries and hence the global growth rates will be overstated.

3. The population growth rate assumptions used in the climate change models reflect the growth rates of 20 years ago not those of today. During this time, global population growth has decreased from 2.5% per annum to 1.2% per annum.

4. There are no estimates of the robustness of the climate change projections to the various assumptions in the models.

In the third IPCC report too much emphasis was on presenting the results as an estimated range of 1.6 to 5.8 degree increase by 2070 implying this is a rectangular distribution with many commentators interpreting this as meaning each outcome is equally likely. This is not the case. The median projection, based on the full range of scenarios, is towards the lower end of the range. The upper level of the range is a scenario based on more extreme assumptions. Yet, in my country, we get many media reports suggesting Australia's temperature will increase by 6 degrees by 2070. The IPCC did not say this but the way they presented the results in documents most accessed by the public did not discourage this support of response.

I am pleased to say that in the fourth IPCC report, this problem has largely been addressed. There is much more information to enable the distribution of the scenarios to be assessed. Importantly, they have provided a best estimate for each of the scenario groupings.

The first criticism is the one that has had most public debate. I will try to explain what happens as a result of using market exchange rates rather than purchasing power parities. The main impact is at the starting point for the models – 1990. Because market exchange rates are used to compare the size of developing economies, there is a tendency to under-estimate the size of developing economies compared with the developed economies which in turn are over-estimated. This is because market exchange rates tend to under-estimate the 'true' comparative costs of developing countries (ie goods and services seem relatively cheap in developing countries). So, with a lower base than there should be and the economic convergence assumptions, growth rates tend to be exaggerated for developing countries. The impact is clearly shown for scenarios A1 and B1 in Table 1 below where more rapid economic convergence is assumed and the growth rates seem very high.

Table 1 Comparative Annual Growth Rates in GDP (on a per capita basis)

Scenario/Source	Annual Growth Rate (%)
A1	3.1
B1	2.4
US Department of Energy	1.9
B2	1.8
World Bank	1.8
International Energy Authority	1.5
A2	1.0

The economic growth rates for the A1 and B1 scenarios are much greater than for the US Department of Energy's, World Bank's or IEA's economic projections. I believe the reason is what I have outlined above ie the non-use of purchasing power parities, combined with convergence assumptions for many scenarios. In fact the data set above indicates that the economic convergence assumption rather than the non-use of PPPs may be the main reason for the high level of economic growth implicit in these scenarios. Why not use the authoritative World Bank comparative growth assumptions in at least one scenario set? I find the arguments that this estimate is not in the peer reviewed literature very hollow – it probably is more authoritative than most of those in the peer reviewed literature.

The differences are greatest for the so-called Africa/Latin America/Middle East region (which comprises most of the developing countries) where the growth rates in the A1 and B1 scenarios are clearly above the upper end of the projections from the DoE, World Bank and IEA whilst A2 and B2 scenarios fall near the centre . This reinforces my argument that the non-use of PPPs, together with the convergence assumption, may be leading to an upward bias in the economic growth assumptions in the A1 and B1 scenarios. This, in turn, will lead to estimates of excessive growth in energy demand and emission levels.

With respect to the second criticism, the World Bank also provides regional growth projections which could be used instead of convergence assumptions. Indeed these estimates imply a level of convergence between the regions.

The impact of these flaws may not be as great as perceived. I understand the bias affects both the numerator and denominator in the models. For example, the amount of technology change leading to energy efficiency is also based on economic growth rates. Also a high proportion of the greenhouse gases are already in the system. Independent sources suggest the overall impact may result in an upward bias of up to 0.5 degrees in the best estimate from the relevant scenarios. Although this does not change the overall conclusions of the climate change modelling, it may still be important and retaining this statistical flaw in the models provides ammunition for the critics and undermines the overall credibility of the work of the IPCC. And suggestions have been made for practical ways on incorporating PPPs into the climate change models by Nordhaus, for example, in his paper for the IPCC Seminar on Emission Scenarios.

Turning now to the third criticism about population growth assumptions, this may be the most important of my criticisms. The official population projections produced by the international community are not used because they are not in peer reviewed literature. Yet they are probably more authoritative and up-to-date than most in the literature. Population growth has slowed remarkably in recent years and many of the peer reviewed projections would not have caught up to this more recent trend. This has been driven by changes in Africa and Asia in particular. In both continents, fertility rates have declined substantially and in Africa mortality rates have increased because of the AIDS epidemic. Mortality has also increased in the former Soviet countries chiefly because of lifestyle reasons. The differences for the regions mentioned above are so great that some commentators have suggested they stretch credibility. The IPCC have noted this in their report and they do plan to incorporate lower population projections in the scenarios being developed for the fifth report.

The annual growth rate from the medium United Nations population projections is 13 to 19% lower than those in B2 and will be even lower than those in A2. However they are broadly consistent with those in A1 and B1. In fact they show peak slightly early than the medium UN projection. Scenarios A2 and B2 assume continually increasing population whereas A1 and B1 assume a population that peaks mid century.

It is interesting to note that difference between the best estimates for A1B and A2 as well as B1 and B2 is 0.6 degrees. This gives an order of magnitude estimate of the impact of the different population assumptions.

Why not develop a set of scenarios based around the authoritative economic and population growth assumptions?

With respect to the fourth criticism, it would be very useful to have estimates showing a robustness of the scenarios to changes in the key assumptions. Taking the A1 family as an example,

- What would happen if the World Bank's projections of economic growth were used instead of these currently used?

- What would happen if higher population growth assumptions were used?

In working out how to adapt to climate change, governments and others are engaging in a form of risk management. It would help them considerably if they were better able to answer a range of 'what if' questions such as those posed above.

4. Validity of the Scenarios

In light of the above analysis, I would make the following comments on the likelihood of various scenario groups.

A1 - Unlikely to occur because economic growth assumptions are unrealistically high.

A2 - Unlikely to occur because population growth assumptions are unrealistically high

B1 - This is the most likely to occur although it probably overstates the degree of economic convergence (but this appears to be less important than the population growth assumptions)

B2 - This is unlikely to occur because of unrealistically high population growth assumptions.

It may be timely to remind ourselves of the most important projections for B1. The starting point I am using is 2007 so have made adjustments to the IPCC estimates which use 1990 as its starting point.

	Best Estimate	Likely Range
Temperature change to 2030	0.5	0.3 – 0.75 dgs
Temperature change to end of century	1.5	0.8 – 2.6 dgs
Sea level rise to end of century	n.a	0.15 – 0.35m

5. What would I advise policy makers?

My competence is as a statistician so I should not provide advice beyond this competency. Given this, I would advise the following:

1. Climate is extremely variable. It is unwise to read too much into short term variations. For example much of south and east Australia is going through a very dry period but there have been two similar dry periods since 1900. This dry period may or may not be due to climate change.

2. There has been definite global warming since 1900 and associated rises in sea levels. These increases are statistically significant. Furthermore statistical models have demonstrated clearly that human activity (especially greenhouse gas emissions) has been a major contributing factor to global warming and associated impacts.

3. Although not yet statistically significant, there are clear signs of distributional impacts from global warming. In Australia, the northern areas appear to be becoming wetter and the southern and eastern areas becoming dryer. Cyclonic activity seems more frequent in the northwest and less frequent in the north east. There also appear to be more frequent extreme events. Although these trends are not statistically significant, and may be due to natural climate variability, the distributional impacts are consistent with climate change models.

4. Without steps to address greenhouse gas emissions further climate change and rises in sea levels could be expected. The impacts are cumulative which increases the importance of addressing this issue before the accumulations become too great.

5. The best estimate of temperature increase to 2030, under a range of scenarios, is an increase in temperature of 0.5 degrees (range 0.3 – 0.75) and an increase in sea levels of 8 centimetres. Higher estimates in this range are unlikely because they are based on scenarios with unrealistically high growth rates. The distributional impacts and possible increase in extreme events may be important from a policy perspective and some allowance should be made for this.

6. Looking further out there is a greater degree of uncertainty in the projections but the B1 group of scenarios is the most consistent with authoritative assumptions on economic growth and population growth. According to this range of scenarios temperature change from now to the end of the century is estimated to be 1.5 degrees (range 0.8 – 2.6) with the range of sea level increases from 15 – 35 centimetres.

7. Given that there is still a lot of uncertainty on what might happen, an adaptive approach might be considered. For example, policies could be based on best estimates at present with some hedging for risks but regular reviews of the situation as more information on climate becomes available.

6. Conclusions

My conclusions are:

1. There are significant statistical flaws in the climate change models which tend to exaggerate the extent of future climate change.

2. The IPCC has been reluctant to correct these flaws but seems to be considering revised scenarios on population projections in their Fifth Assessment. In the meantime, a trusted body such as the OECD should be commissioned to assess the impact of these flaws so governments have the best evidence base on which to develop climate change policy. Specifically, it should develop climate change projections using scenarios based on authoritative estimates of economic and population growth with the use of PPPs to when aggregating economies along the lines suggested by Nordhaus.

7. References

IPCC (2007), Climate Change:The Physical Science Basis, Summary for Policymakers

IPCC (2007), Working Group III report for the Fourth Assessment Report