

Climatic Impacts on Developing Countries

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DEVELOPING COUNTRY IMPACTS IN INTEGRATED ASSESSMENT MODELS OF CLIMATE CHANGE.

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Abstract

Integrated assessment models of climate change have not paid much attention to the characterisation of impacts in developing countries. Optimizing models in particular tend to lack much spatial disaggregation. Even when developing countries are explicitly considered, the major concern has been to model their likely emissions. Studies of impacts show that they are likely to be greater in developing countries than in the developed world, and do merit more attention in models.

The PAGE95 integrated assessment model has been developed to work in conditions of profound uncertainty. It divides the world into eight regions, and represents developing country impacts with almost the same detail as those in the OECD. Early results from the PAGE95 model show that climate change impacts are likely to be at least 10% of GDP in India, Latin America and Africa by 2100, if the IS92a emissions path is followed, while no OECD region will be losing more than 3% of GDP. These results strongly suggest that developing country impacts will be larger than those in the OECD in absolute terms and as a percentage of GDP, and more uncertain.

Introduction

Integrated assessment shares with sustainable development both a high level of recognition as a term, and a low level of agreement about what exactly the term means. Parson (1995) regrets this 'substantial confusion and fruitless definitional debate [that] has surrounded the concept of integrated assessment.' He defines assessment, in contrast to pure research, as 'the presentation of knowledge...to help someone...evaluate possible actions or think about a problem', and declares that for assessment to be integrated it must 'assemble...information from a broader set of domains than would typically be provided by good research from a single discipline' (Parson, 1995).

Applying this general definition to climate change, Dowlatabadi (1995) states that integrated assessments in this field '...incorporate our knowledge about precursors to, processes of, and consequences arising from climate change' and that this almost inevitably involves a computer model of some kind.

From a handful of models in the early 1990s, the recent IPCC second assessment report identified 22 Integrated Assessment Models (IAMs) of climate change, although only 15 were at that time fully operational (Bruce et al, 1996, p381). The major division is between policy optimization and policy evaluation models. As their names suggest, policy optimization models seek to identify the best possible policy to meet a goal, while policy evaluation models take specific policies and project, or simulate their consequences.

Spatial disaggregation

Table 1: Summary characterisation of integrated assessment models

Model	Forcings	Geographic Specificity	Socioeconomic Dynamics	Geophysical Simulation ^a	Impact Assessment ^b	Treatment of Uncertainty	Treatment of Decision Making
	0. CO ₂ 1. other GHG 2. aerosols 3. land use 4. other	0. global 1. continental 2. countries 3. grids/basins	0. exogenous 1. economics 2. technology choice 3. land-use 4. demographic	0. Global ΔT 1. 1-D ΔT, ΔP 2. 2-D ΔT, ΔP 3. 2-d Climate	0. ΔT 1. Δsea level 2. agriculture 3. ecosystems 4. health 5. water	0. one 1. uncertainty 2. variability 3. stochasticity 4. cultural perspectives	0. optimisation 1. simulation 2. simulation with adaptive decisions.
AS/ExM	0	0	0	0	0	1	2
AIM	0,1,2,3	2,3	1,2,3,4	1,2	1,2,3,5	0	1
CETA	0,1	0	1,2	0	0	0 or 1	0
Connecticut	0	0	1	0	0	1	0
CRAPS	0	0	1	0	0	1	2
CSERGE	0	0	1	0	0	1	0
DICE	0	0	1	0	0	0 or 1	0
FUND	0,1	1	1,4	0	0,1,2,3,4	0 or 1	0
DIAM	0	0	1,2	0	0	0 or 1	0
ICAM-2	0,1,2,3	1,2	1,3,4	1,2	0,1,3	1,2,3	1,2
IIASA	0	0	1	1	2	0	0
IMAGE 2.0	0,1,2,3	3	0,2,3	2	1,2,3	1	1
MARIA	0	0,1	1	0	0	0	0
Merge 2.0	0,1	1	1,2	0	0	0 or 1	0
MiniCAM	0,1,2,3	2,3	1,2,3	2	0	0	1
MIT	0,1,2,3	2,3	1	2,3	0,0,2,3	1	0,1
PAGE	0,1	1,2	1	0	0,1,2,3,4	2	1
PEF	0,1	1,2	1	0	0	2	1
ProCAM	0,1,2,3	2,3	1,2,3,4	2	0,2,3,5	1	1
RICE	0	1	1	0	0	0	0
SLICE	0	1	1	0	0	1	2
TARGETS	0,1,2,3,4	0	1,2,3,4	2	1,2,3,4	4	1,2

Source: IPCC Second Assessment Report

^aTARGETS includes ozone depletion, soil erosion, acid rain, and toxic and hazardous pollutant releases.

^bIn AIM, FUND, IMAGE, PAGR, and ProCAM, the impacts are calculated separately for each sector.

Source: Adapted from Rotmans et al (1995).

Table 1, reproduced from the IPCC report, shows in its third column the spatial disaggregation in the models, and in its last column identifies the models as optimising or simulating. Of the ten optimising models, only four have any spatial disaggregation below the global level (although a new version of CETA with two regions is now also available (Peck and Teisberg, 1995)). In contrast, of the nine simulation models, eight disaggregate at least to

the continental level, and all of these also provide a level of resolution fine enough to pick out the largest or most influential countries, typically the USA and China.

The reason is not hard to find. Optimising models suffer from the 'curse of dimensionality': the difficulty of finding a solution goes up rapidly as the number of independent decision variables increase. Moving from a global to a two-region model usually more than doubles the number of decision variables, depending on how trade between the regions is handled. This can easily lead to an order of magnitude increase in the difficulty of performing the optimisation. Nordhaus and Yang (1995), explaining the four year gap between the first experimental version and the operational version of RICE, commented that 'a major cause of the long gestation period has been the difficulty in finding a satisfactory algorithm for solving the intertemporal general equilibrium'.

Policy evaluation models do not suffer from the curse of dimensionality. Doubling the number of regions typically involves only about a doubling of complexity. However, even the policy evaluation models typically split the world into only about a dozen regions or fewer (Dowlatabadi, 1995). No wonder the IPCC report included 'developing realistic representations of the dominant processes and policies in the developing countries' as one of the five biggest challenges facing integrated assessment modellers (Bruce et al, 1996, p391).

Focus on the OECD

However, a closer look at the IPCC report shows that the major concern is not with the representation of impacts in the developing countries, but with the representation of their emissions. 'The contribution of these countries to climate change and their responses to it are likely to be influenced by other more immediately pressing concerns. Three of the most critical such issues in the developing countries are land use, land tenure and population' (Bruce et al, 1996, p391).

It is perhaps not surprising, this focus on the need to improve the modelling of emissions from developing countries. All the 22 presently operational IAMs are located in OECD countries, and many have been funded by organisations whose main concerns lie with the welfare inside those countries.

Although there is a clear recognition in all the models that climate change is a global problem, it is the emissions from developing countries that will have a direct effect upon welfare inside the OECD; the impacts in developing countries have an indirect effect at most, perhaps via the route of decreased exports from the OECD, or of some altruistic concern amongst the people in OECD countries for the plight of those less fortunate than themselves.

Many OECD countries struggle to reach UN recommended minimum levels of assistance to the present generation in developing countries. So it is not too surprising that the level of concern in the OECD for impacts upon future generations in the developing countries is patchy.

A more charitable explanation for the lack of effort directed at modelling impacts in the developing countries would be that the availability of data to feed into the models is poor. Accurate statistics on public health, land use, coastal vulnerability, which are taken for granted in the OECD, are sadly lacking in many developing countries. With most IAMs unable to run under uncertainty, a simple best-guess for developing country impacts is the most that it is reasonable to demand.

Developing country impacts are substantial

The lack of attention paid in IAMs to modelling the impacts in developing countries does not imply that those impacts are likely to be small. Quite the opposite seems to be the case. Of the six factors of location, economic structure, coastal vulnerability, rigidities, human health and valuation, only location would suggest that developing countries would be less affected than OECD countries. Economic structure, coastal vulnerability, rigidities and human health suggest that developing countries would be more affected, while valuation appears broadly neutral when damage is measured as a percentage of GDP (Bruce et al, 1996, p207) (although not all agree with the last statement; the controversy over valuation was one of the most bitter struggles inside IPCC working group III).

The estimates of Fankhauser (1995) and Tol (1995) seem to bear out this suggestion of higher impacts in developing countries. Table 2 shows their estimates. Damages from a doubling of CO₂ concentration for the non-OECD regions are estimated at 1.6 and 2.7% of GDP, against 1.3 and 1.6% of GDP in the OECD.

Table 2: Monetized damage for a doubling of CO₂ concentration by world region and publication

Region	Fankhauser (1995)		Tol (1995)	
	bn\$	%GDP ^a	bn\$	%GDP ^a
European Union	63.6	1.4		
United States	61.0	1.3		
Other OECD	55.9	1.4		
OECD America			74.2	1.5
OECD Europe			56.5	1.3
OECD Pacific			59.0	2.8
Total OECD	180.5	1.3	189.5	1.6
E. Europe/ Former USSR	18.0 ^b	0.7 ^b	-7.9	-0.3
Centrally planned Asia	16.7 ^c	4.7 ^c	18.0	5.2
South and Southeast Asia			53.5	8.6
Africa			30.3	8.7
Latin America			31.0	4.3
Middle East			1.3	4.1
Total non-OECD	89.1	1.6	126.2	2.7
World ^d	269.6	1.4	315.7	1.9

^aNote that the GDP base may differ between the studies.

^bFormer Soviet Union only

^cChina only

^dPercentage of GDP figures are based on market exchange rate GDP. The order of magnitude of estimates does not change if uncorrected damage categories are purchasing-power-parity adjusted and expressed as a fraction of PPP-corrected GDP.

Sources: As Shown.

The IPCC report cautions that the estimates are 'probably biased towards convergence...The similarity of the estimates should therefore not be interpreted as evidence of their robustness. A substantial degree of uncertainty remains' (Bruce et al, 1996; p205).

The remainder of this paper gives an indication of the way in which such estimates are incorporated in one of the IAMs that can cope with substantial uncertainty, the PAGE95 model. It shows that we are potentially moving towards a requisite treatment (Phillips, 1984,

defines a requisite decision model as one whose form and content are sufficient to solve a particular problem) of developing country impacts.

The PAGE95 model

The general form of the PAGE95 model is shown in Figure 1. In the terminology of the IPCC report, PAGE95 is a policy evaluation model. Policies to abate and adapt to climate change are specified by the user, and PAGE95 calculates their implications.

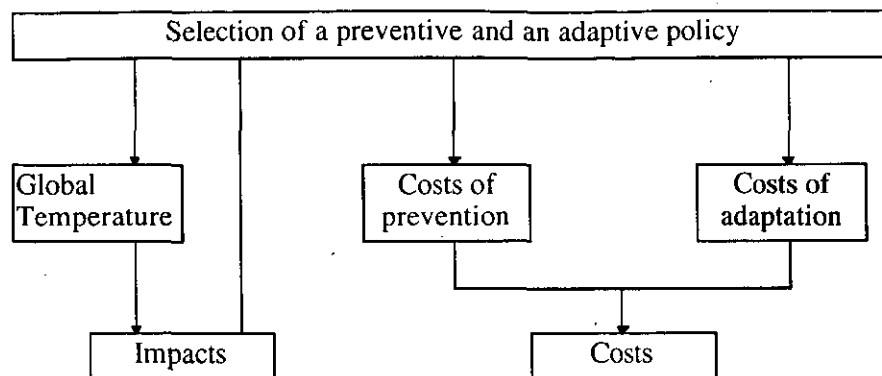


Figure 1: The Form of the PAGE model.

PAGE95 is entirely dependent for its inputs on more detailed primary studies, such as GCMs for the science of climate change (Houghton *et al*, 1996), Tol (1995) and Fankhauser (1995) for impacts, and Barker *et al* (1993) for costs of abatement.

PAGE95 contains equations that model:

- Emissions of the primary greenhouse gases, CO₂ and methane. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), decision variables in the original PAGE model (Hope *et al*, 1993), have a reduced role in PAGE95. Although future emissions are limited by international agreements to protect the ozone layer, existing atmospheric concentrations are not expected to decline significantly in the next century. Hence PAGE95 models (H)CFCs as a small addition to background radiative forcing, small due to the cooling effect of ozone depletion.
- The greenhouse effect. Anthropogenic emissions of greenhouse gases exceed the rate of removal by chemical and biological processes and accumulate in the atmosphere. The greenhouse gases trap heat in the atmosphere so that less of the incoming solar radiation is re-radiated to space. This increases radiative forcing, the net flux of energy to Earth. The Earth's temperature rises very slowly as excess heat is transferred from the atmosphere to land and ocean.
- Cooling from sulphate aerosols. Sulphate aerosols result from fossil fuel combustion and are commonly known as the cause of acid rain. They also backscatter incoming solar radiation and interfere with cloud formation, producing a reduction in radiative forcing. This counteracts the greenhouse effect.

- Regional temperature effects. Unlike greenhouse gases which remain in the atmosphere for decades and are globally mixed, sulphate aerosols have a very short atmospheric lifetime (about 6 days) and so tend to remain in the source region. Therefore sulphate aerosol cooling is a regional phenomenon. For the eight world regions in PAGE95, temperature rise is computed from the difference between global warming and regional sulphate aerosol cooling. Sulphate cooling is greatest in the more industrialised regions, and tends to decrease over time due to sulphur controls to prevent acid rain and negative health effects.
- Nonlinearity in the damage caused by global warming. Climatic change impacts are a polynomial function of regional temperature increase above some tolerable level of temperature change, $(T - T_{tol})^n$, where n is an uncertain input parameter.
- Regional economic growth. Impacts are evaluated in terms of an annual percentage loss of GDP in each region, for a maximum of two sectors- usually defined as economic impacts and non-economic (environmental and social) impacts.
- Adaptation to climate change. Investment in adaptive measures (e.g. the building of sea walls; development of drought resistant crops) can increase the tolerable level of temperature change (T_{tol}) before economic losses occur and also reduce the intensity of both non-economic and economic impacts.

All aspects of the global warming problem are subject to profound uncertainty. To express the model results in terms of a single 'best guess' could be dangerously misleading. Instead, policy should be informed by a range of possible outcomes. Therefore PAGE95 represents more than 70 key input parameters by probability distributions. Random sampling is used to build up an approximate probability distribution for the model results. The comprehensive scope and probabilistic formulation of the model necessitate the simplest credible equations. These equations and the probability distributions for key input parameters are described in Plambeck *et al* (1995) and Plambeck and Hope (1995).

Spatial disaggregation in the PAGE95 model

The PAGE95 model splits the world into eight regions, one of which is designated the focus region. Table 3 shows the present designation of these regions, but the model is completely flexible. Other users could set up the model with a different regional split and a different focus region, the USA say, or China.

Table 3: Regions in the PAGE95 model

European Union ¹
Eastern Europe and the former USSR
United States of America
India and South East Asia
Latin America
China and centrally planned Asia
Africa and the middle east
Other OECD

¹ Focus region

Table 4 shows the main classes of inputs to PAGE95, and the extent to which they are region specific.

Table 4: Classes of input in the PAGE95 model by degree of regional specificity

Input class	Specificity
Emissions	Complete
Adaptation policy	Complete
GDP	Complete
Uncertainty in BAU emissions	Factor
Natural sulphate flux	Complete
Thermal lag	None
Tolerable temperature change	Factor
Valuation weights	Factor
Impact exponent	None
Control cost values	Factor
Control cost ranges	Complete
Costs of adaptation	Factor
Discount rates	Complete

If a class of inputs is completely region specific, it means that each input of that type is specified independently for each region. Thus in PAGE95, the emissions of each greenhouse gas in each analysis year (presently implemented as every 20 years from 2000-2100, every 25 years from 2100-2200) is specified separately for each of the eight regions.

If a class of inputs is specified as a factor, it means that the class of inputs is specified completely for the focus region, and then specified for other regions a single multiplicative factor that is applied to all the focus region values. Thus in PAGE95, the valuation weights are specified for the focus region (in terms of the percentage GDP lost per 2.5 °C, non-economic impacts range from 0.3 to 3.5 with most likely value 0.7; Economic impacts range from 0.3 to 1.5 with most likely value 0.6, for example), and economic and non-economic impacts in the other regions are computed as a multiple of the focus region values (for example, percent GDP lost per 2.5 °C in India and South East Asia is between 1 and 7.9 times the value for the focus region, with most likely value 6.6). This gives less regional specificity than for those inputs that are completely region specific, as the same regional factor is used for both the economic and non-economic valuation weights. The main reason for using such a class of inputs is to keep down the number of probabilistic input distribution that need to be specified. For valuation weights, it means that only nine uncertain inputs need to be specified (economic and non-economic weights for the focus region, plus seven region-specific factors), rather than 16 (economic and non-economic weights for all eight regions).

If a class of inputs is not region specific, it means that only a single probability distribution is used for all regions. Thus only a single probabilistic value for the impact exponent is used across all regions of the world. Impacts are assumed to be a polynomial function of temperature rise above the tolerable level. In the present implementation of PAGE95 the power lies between 1 and 3, with a power of 1.3 as the most likely value. This value is used for the focus region, for the rest of the OECD and for non-OECD regions alike.

Some results

Table 5: Mean impacts of climate change by region and year

<i>2000 - 2100</i>			<i>percent of GDP</i>			
Region	2000	2020	2040	2060	2080	2100
EC	0	0	0	0	1	2
EE	0	0	0	0	0	0
US	0	0	0	1	2	3
India etc	1	1	2	2	5	10
Latin	1	2	3	5	7	11
China etc	0	0	0	2	4	7
Africa etc	3	3	4	6	9	14
Other OECD	0	0	1	1	2	3
Total	0	0	1	2	4	7

Source: PAGE95 model results

Table 5 shows the mean results from the PAGE95 model, for the total impacts of climate change in each of the eight regions up to 2100 for the IPCC scenario IS92a. Economic and non-economic impacts are included, and all results are expressed to the nearest percent of regional GDP in the same year. These mean results confirm the impression that developing countries will be hit hardest, particularly towards the end of the next century. As a mean result, India, Latin America and Africa will all be losing 10% of their GDP or more by 2100 if the IS92a emissions path is followed, while no OECD region will be losing more than 3% of GDP.

In absolute terms, the disparity between OECD and developing countries is also great; developing countries will lose over \$15 trillion of the estimated \$18 trillion impacts in 2100, again taking the mean results. All these impacts increase rapidly in the 22nd century if nothing is done to abate emissions.

The reasons for the predominance of developing country impacts is not just the extra vulnerability to climate change highlighted in the IPCC report. The rapid growth of developing country populations and economies, and the lower ability to adapt to climate change by protecting vulnerable coastlines, or moving to other types of agriculture, are also important.

Table 6: Range of climate change impacts by year and region

<i>2000 - 2100</i>			<i>\$billion</i>			
Year	USA			China		
	<i>min¹</i>	<i>mean</i>	<i>max²</i>	<i>min¹</i>	<i>mean</i>	<i>max²</i>
2000	0	1	4	0	5	21
2020	0	14	60	0	16	78
2040	6	64	194	0	38	204
2060	27	188	513	6	268	1060
2080	65	430	1040	165	1140	3400
2100	148	873	2380	740	3790	9690

¹ 5% point on probability distribution

Source: PAGE95 model results

² 95% point on probability distribution

Table 6 shows the range of impacts for two regions, the USA and China in absolute values, also for the IPCC scenario IS92a. Although the mean value is larger for China than the USA by 2060, and is four times as large by 2100, the lower value (5% point on the probability distribution) is lower for China than the USA until 2080. There are two reasons for this: the lack of knowledge about impacts in developing countries already highlighted, but also the emissions of large quantities of sulphates in China until after the middle of the next century, which may (or may not, we don't know for sure), delay the onset of climate change in that region.

Conclusions

The impact of climate change in developing countries has been relatively neglected in integrated assessment modelling up to now. Preliminary results suggest strongly that developing country impacts will be larger than those in the OECD in absolute terms and as a percentage of GDP, and more uncertain. Models with a thorough handling of uncertainty, such as PAGE95, offer some hope of providing a requisite treatment of developing country impacts in the near future. To return to where we started, it seems that on any definition of sustainable development, these developing country impacts do need to be more carefully addressed.

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