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A DESCRIPTION OF THE CICERO INTEGRATED CLIMATE MODELLING APPROACH

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1 INTRODUCTION

I enjoyed the title that was given to this presentation, which is why I let it pass without comments. However – or perhaps therefore – I must admit that it is somewhat overambitious if interpreted as a promise to present a complete integrated model with a new and original method – or approach – that no-one else has ever thought about. Let me, therefore, start by saying that CICERO has been working over some years with aspects of integrated assessments from which the image of an approach to integrated modelling can be drawn. A complete model that corresponds to such an image is, however, not yet established. We have only developed a couple of small modules that focus on some issues that we believe are important. We have also started on the development of a general model which will be based on a regionalized general computable equilibrium model that will include these modules. In this presentation I will try to explain the basic "philosophy" behind this image of an integrated model, but I will have to confine myself to a more fragmented picture when I show, by examples, how we suggest to model environmental impacts of economic development and how the results can be interpreted.

2 THREE PILLARS ON WHICH INTEGRATED MODELLING ARE BASED

One of the main challenges facing those who work with so-called integrated analysis is to try to retrieve as much knowledge as possible from the broad range of disciplines that can be considered relevant for analyses of climate change. This is probably acknowledged by most people, but I suspect that the potential for improvements is still large. One reason why is that I think economics has much more to supply than valuation in terms of pricing some physical phenomenon, which is what we are usually asked to provide. From my own perspective, I often complain that economics in the view of non-economists seems to be identical to the art of attaching prices to everything. Beyond that, they find economics both disturbing and confusing.

With such a limitation, I think that the economists' contribution to the evaluation of impacts of climate change is much more constrained than it needs to be. The reason is, first and foremost, that estimates of the 'damage cost' are usually not based on a consistent set of prices. This has to be so in so-called bottom-up assessments, but top-down approached model studies are also often based on inconsistent set of prices. This may be vital to the results because we are primarily concerned about the impacts in the very long run, when climatic changes might be considerable and the relative value between economic products and protection of the environment may change accordingly.

A major advantage with general equilibrium models is that they allow prices to be determined endogenously. Hence, to the extent that economics might contribute to integrated assessments, it is vital that the shadow prices of impacts of climate change are endogenous. As a consequence, the relationship between quantities of produced and demanded goods and services and the physical climatic variables, such as temperature, precipitation and wind, should be modelled. For example, the integrated model should not include estimates of the cost of more umbrellas and raincoats to represent an impact of more precipitation. Instead, we need to find how many more umbrellas and raincoats will be demanded.

The second issue to raise in response to my complaint about other people's demand for economic input is, of course, that there is a fair chance that this complaint could be turned the other way around: As economists, we probably do not take sufficient advantage of the information other disciplines can provide to our own understanding of economic relationships.

Reading the second volume of IPCC's Third Assessment Report about impacts, adaptation and vulnerability (TAR, Vol. II) gave nutrition to my suspicion in this respect. It seems that analyses and assessments of impacts of climate change are being developed in – at least – two very different worlds. On the one hand impacts are being assessed with the purpose of integrated modelling. These typically provide damage cost estimates – adjusted for adaptation in recent years – and are based on tools and methods familiar to an economist. In fact, the methodological tools and challenges related to impacts assessments discussed in Chapter 2 of TAR, Vol. II are those that we economists struggle with, such as uncertainty, costing and valuation, and tools for decision making.

The remaining 16 chapters of TAR Vol. II survey various studies of impacts, adaptation and vulnerability. What strikes me is that the issues discussed under "methods and tools" in Chapter 2 are more or less absent in all of these chapters. In other words, there seems to be a lack of compatibility between the practitioners who work out assessments of effects, impacts, adaptation and vulnerability and those who discuss methods and tools for damage cost assessments and integrated modelling.

I became aware of this when I tried to find tools and methods for utilising results from more focused studies of sectors or certain climate phenomena – of which there are many – to a national assessment for impacts of climate change in Norway, about two years ago. I came out more or less empty handed. It is not that aggregated assessments of damage costs do not refer to more focused studies, but I could not find a systematic approach to collect and aggregate various impacts studies to a national scale. It is not only of interest to see how a result from a study of impacts on a disaggregated level contributes to an assessment of national impacts. Such a "translation across scales" also makes detailed knowledge of high quality and relative certainty relevant for national policy making. In this perspective, also the integrated model should – as far as possible – reflect the current level of knowledge about impacts. The second pillar of the integrated model is, therefore, that it should be based on an approach to translate results from 'sector studies' into a common framework for analysis of impacts on the national scale.

The third pillar of the integrated model is that it should support assessments with a clear and outspoken purpose. The idea of integrating a lot of various aspects in one model easily leaves the impression that one try to say everything there is to say about impacts of climate change. It is worth bearing in mind that modelling is rather characterized by the opposite, namely to help define what can be left out of the analysis. Although trivial, this often turns out to be controversial because it means that we sort out what is important and what is not. Of course, there is no objective answer as to what is important or not in general, but it is possible to sort out issues and topics if the purpose is specific enough.

For example, whether an increase in the probability for river flood is important or not depends on who you ask. A family that lives nearby the river will, no doubt, be worried. The local authorities, who knows that this is the only family living nearby the river, will perhaps be satisfied by encouraging the family to find an alternative building lot, while the national authorities, who also consider the 50 000 people living nearby the river in the neighbouring county, may have a very different view. What is important can not be answered unless we know who asks the question. Over the recent years, there is a tendency to develop impacts studies towards narrowing the focus, greater detail and heavier emphasis on the 'tails' of the probability distributions. This has been applauded because it allows the consequences of climate change to be predicted more precisely. This is good, but not under any circumstance. It also leads to further fragmentation, difficulties in comparing results, and greater difficulties in considering the consequences of simultaneous changes, which is bad for the task of making national assessments. The purpose of the work on integrated modelling at CICERO is rather the opposite: to generalise results from focused studies of sectors or changes of certain climate phenomena to an aggregated level in order to support decision making on the national- or on a regional level.

3 A GENERAL FRAMEWORK FOR ASSESSMENTS OF NATIONAL IMPACTS OF CLIMATE CHANGE

A point of reference for an integrated model to assess socioeconomic impacts to a country or a region could be a multi-sectoral macroeconomic model. In my view, the input-output structure constitutes the heart of such a model. Interpreted as technology parameters, the question of impacts of climate change could be phrased as a question of how the input-output flows will be affected if a known change of climate occurred. There are three classes of impacts to consider in this context:

i) The impacts of intermediate demand for input factors in production sectors. A change in the precipitation pattern, for example, may require farmers to use more fertilizers – or allow them to use less – to produce the same quantity of output as before. Higher temperature will change the demand for energy through heating or cooling. That is, to produce the same output quantity, the input of energy will have to change.

ii) The impacts on final demand, consumption, export products and investments. Many possible impacts. Umbrellas and raincoats are mentioned. Among possible sizable impacts, we mention energy demand, which will change for the same reason as under i) and the demand for tourist services, both from the country's own citizens, and from foreign visitors. Investments include adaptation measures to meet expectations about future changes.

iii) The impacts on productivity. Could affect a long range of factors, but the most important is productivity changes related to a change in stock of natural and environmental resources in resource based sectors. This is, or course, because natural resources and the environment may be particularly sensitive to climate change.

The first two categories include impacts on the demand side of the economy, while the third category affects the supply side. From this point of view, impacts of climate change can be expressed in terms of shifts in supply and demand. To be more specific, denote by Δx the change of an economic activity resulting from a change, ΔT, of a vector of climatic variables. Then, the first step of an impact assessment would be to determine the relationship $\{f: \Delta T \rightarrow \Delta x\}$ on the basis of available studies, which I call sector studies. How can this be done?

First, the sector studies have to refer to the same climate scenario. This requires that such a scenario exists. Results from 3-dimensional global circulation models, GCM, are usually too rough to be applicable in this context, but many countries now use down-scaling techniques to develop climate scenarios with reference to specified GCM-runs. These provide information on a much more detailed grid. The Institute of Meteorology at the University of Oslo develops scenarios for the coming 50 years for Norway. Roughly speaking, they forecast more rain and higher temperatures in all regions of Norway all through the year. The most significant temperature increase is expected in the northern Norway in winter, and precipitation increases the most in the western part in the autumn. This is the place where, and the time when, it is already raining the most at present.

A national assessment will have to be based on sector studies worked out in different years with different expectations about climate change. In many cases, the information about the climatic factors is also incomplete. For example, temperature increase may be given without information about precipitation, the annual averages are often reported without seasonal variation, or the national aggregates are given without specification of the regional distribution.

Second, the results from the sector studies will have to be transformed on to the denomination of supplied and demanded quantities. This means that the human response to changes in the climate will have to be predicted. In some cases, this is appropriately taken care of in the sector study. For example, the impact on energy demand for heating purposes from a change in the temperature is known from the 'temperature adjusted energy demand' which is reported regularly from the Energy directorate in Norway (cooling is not an issue here). This may be utilised in the impacts assessment as well if we find it acceptable to assume that short-term adjustments made because the temperature differs from one winter to the next are similar to a long-term adjustment to milder winters in general.

In many cases, one will have to use the sector study as the basis for a more general study of the human response to the climatic change before one can tell how the supply or demand are affected. There are two issues to be dealt with, worth mentioning here. One is aggregation. As mentioned, the sector studies very often focus on a small group or a single climate related phenomenon. For a national assessment, the results have to be generalised. This may be a tremendous task, and one might find that the impacts focused in the sector study have no significant impact on the national scale. This does not, of course, mean that the findings of the sector study is unimportant, only that is does not affect the perspective taken in the national assessment. But the process of putting results from various sector studies into a common framework may nevertheless be useful in comparing the results from independent assessments. Without a systematic aggregation of results with a clear and outspoken purpose, it is very difficult to compare large impacts for a small group of people with small impacts for a large group. Again, the tendency towards limitation of focus may be questioned because my impression is that one tends to concentrate on the large impacts, and forget that it often affects very few people.

The second issue worth mentioning in connection to estimation of shifts in the supply and demand is an analysis of the economic behaviour of the agents in question, usually called 'adaptation' when applied to studies of the impacts of climate change. In some cases, the economic behaviour described on the local level cannot easily be "translated" to economic behaviour on an aggregated level. Many sector studies do not even intend to describe economic or social impacts, but limit the focus to the appraisal of physical effects of a change in climatic parameters. Such appraisals are necessary in attempts to determine the shifts in supply and demand, in particular when the sector study deals with changes in the stock of natural resources of relevance for the economy, such as in agriculture, fisheries and forestry. But they constitute only a part of a socioeconomic assessment, for which an economic analysis of the response to such effects is equally important. To illustrate this, we may take a closer look at the impacts on electricity production in a county in the western part of Norway, Hordaland, which we have briefly studied.

It is said that the only good thing about the expected increase in precipitation from climate change in Norway is that it increases the potential for the production of hydro-power, which is the only significant source for electricity in Norway today. In the western region, where most of the production goes on, annual precipitation is expected to increase by 10 – 15 percent over the next 50 years. The common understanding of this is that production of hydro-power will increase accordingly. But this is before the economy of the increase is considered.

Figure 1 shows the run-off, electricity demand and magazine capacity required to produce all the inflow today and in 50 years according to the climate scenarios. The most significant increase in precipitation will be in the autumn. At this time of the year, the magazines today are already full: the major inflow to the magazines starts in the spring when the snow melts and the heating season comes to an end. In the summer, a low demand allows magazines to be filled despite low run-off. A further increase during the fall is due mainly to high precipitation. To take the advantage of more precipitation in the hydro-power sector, the magazines will therefore have to be enlarged. How much depends – not only on the oscillations of inflow and demand – but also on the annual variations in precipitation. If the sector adds a security condition to their deliveries during the winter season, which is quite usual today, the required magazine capacity may be considerably higher.

Figure 1. Run-off, electricity demand and required magazine capacity to produce inflow before and after climate change in Hordaland. TWh

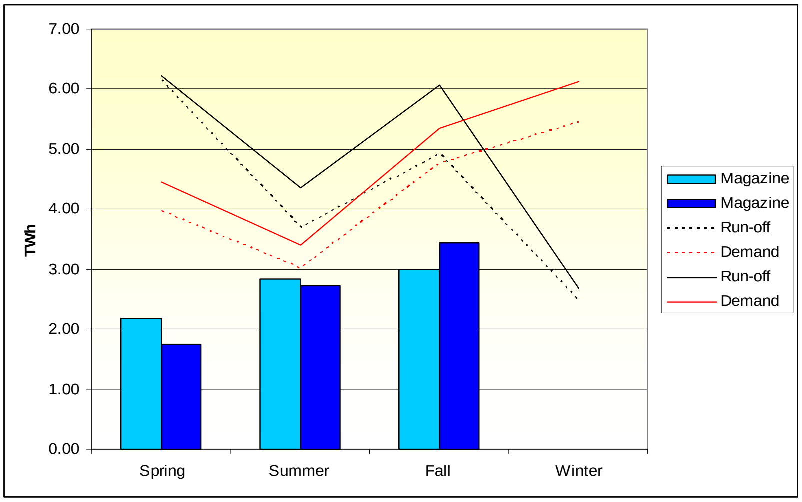
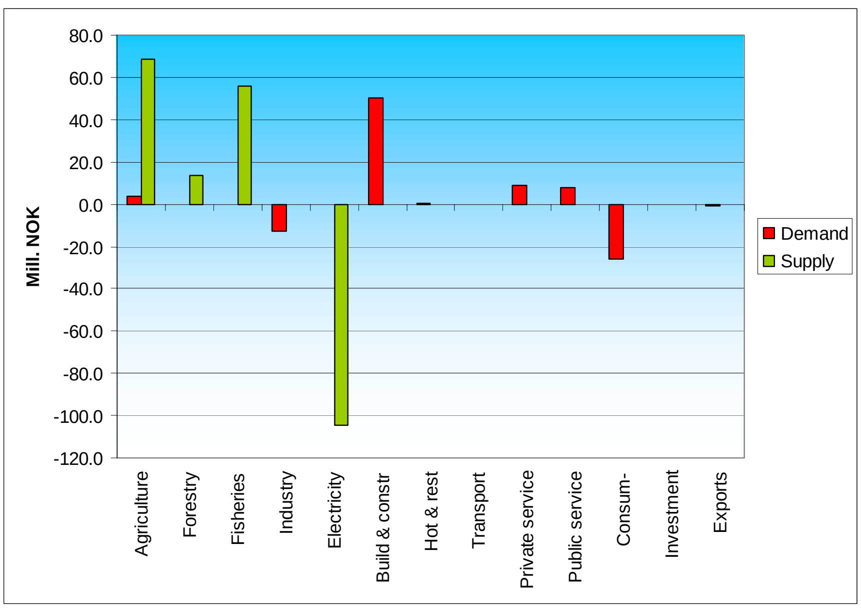


Figure 1 shows the runoff, demand and potential for building up water magazines before and after climate change. The required magazine capacity needed to deliver the total annual run-off to the demand side is the maximum of magazine build-up, which occurs in the fall. Hence, if the increase in the run-off is to be utilised fully, the magazine capacity will have to increase by approximately 15 percent. In addition, the suppliers might want to account for the annual variation of inflow, which is large. Hence, an increase in the annual variation following climate change, which is likely to follow an increase in average precipitation, may lead to a further increase in the required magazine capacity. This depends, however, on the expected loss related to a change in the risk for magazine overflows compared with the cost of an enlargement.

Building hydro power magazines is, indeed, a costly affair. Based on historic data for the average magazine costs, which is likely to be considerably lower than the cost of an enlargement of existing ones, we found that a full extension of the capacity would not pay at all. In other words, and increase in the run-off between 10 to 15 percent gives a negative shift in the productivity of the electricity sector, measured in volume terms. Note, however, that this assumes that the price of electricity remains unchanged in a 50 years perspective. If we expect the electricity market towards Europe to open in foreseeable future, such an assumption is, of course, unrealistic. But this does not change our main point here, which is that impacts of climate change measured in the national accounts' volume terms cannot be read directly out of estimates of the physical effect. Even the volumes strongly depend on economic behaviour in markets, or adaptation.

Before we turn to the modelling on the aggregated level, I would like to add a few words about the outcome of impacts assessment as presented here. The results of the economic evaluation of impacts on the sector level are usually expressed in terms of costs. However, all the changes refer, in principle, to a set of constant prices. The hydro-power example could be presented in terms of the volume enlargement of the magazines, on the one hand, and the volume of higher production, on the other hand. Changes in the cross-deliveries among sectors could also be measured in terms of increases or reductions in volumes. But what about the values?

Figure 2. Estimated shifts in supply and demand following climate change in Hordaland.



Economic assessments of impacts of climate change are often presented as costs, either on a sector basis. Sometimes they are aggregated to a national scale, that is, we hear about a percentage increase of decrease in GDP resulting from a specified change in the climate. With the approach presented here, such a measure is obviously problematic. Figure 2 shows the estimated shifts in supply and demand by sector in volume terms for the county of Hordaland, based on results from sector studies. Some are very rough, others are merely based on guesswork. The figures should therefore be considered only as illustrations.

The light grey bars indicate changes in supply, mainly due to changes in the natural resource base of resource extracting sectors. Hence, the traditional primary sectors expect to gain an increase in the productivity. The most significant relative change is in forestry, which increase output by 30 percent. However, forestry is a very small sector in Hordaland country, and the total impact to the county is therefore moderate. The reduction in electricity supply is due to the aforementioned increase in the required capacity for hydro magazines.

The dark bars indicate shifts in the demand from sectors and final demand, thus indicating increasing costs. The changes displayed in Figure 2 reflect impacts on four activities. First, energy demand decreases in all sectors and in consumption because of higher temperatures in cold seasons. Second, the demand for tourist services decreases because of shorter winter season in winter resorts, and more rain in the summer season. Third, personal transport is assumed to switch from manual and public transport to private transport because of more rainfall. Forth, the demand for building and construction services increases as a response to renewed building standards related to an expected increase in extreme weather events. Alternatively, the latter could be interpreted as an expected cost of damage due to extreme weather events.

What is the aggregated impact of these changes to Hordaland county? One may, of course, add the costs and benefits and end up with a total amount for the county in total. Note, however, that the costs on the demand side are benefits on the supply side. Thus, a positive shift on the demand side is to be interpreted as a social cost, while the positive shift on the supply side is a benefit. A total cost for the county of Hordaland cannot be derived straightforwardly from these numbers. What they tell is rather about the gap between supply and demand after climate change has taken place. To do a consistent analysis of socio-economic impact, we have to feed the volumes estimated so far into an economic model, which include relationships between the vector of adequate climate variables and the technology parameters in the model.

4 MODELLING

The outcome of our attempt to collect and aggregate sector studies according to a "bottom-up" approach is, thus, that the economic impacts of climate change, or the damage costs, depend on the performance of the national economy. This is why I think that integrated models should be something more than just models that include damage costs estimates. We have not yet taken this step in studies of Norway to illustrate the point. Instead I will present some results from a study impacts on the Fijian economy from possible changes in the fisheries. This study is a more traditional integrated study, in the sense that it concentrates only on the impact one climate related activity, the fisheries.

A sector study of the fisheries in the Fiji islands turns out to be rather inconclusive (Lehodey, 2000). Depending of a relatively poorly understanding of ocean currents in the Pacific, global warming may have both positive and negative effects on the fishing stock. Fish – and tuna fish in particular – is important to the country, which must be considered a poor one, where a large part of the population lives in subsistence households. Many of these households are also based on fishing. A change in the stocks may affect the Fijian economy directly, as well as a lot of people not really integrated in the market economy.

We considered three alternative effects of climate change on the stock of fish in Fijian areas. In the first case, the stock of fish in the Fijian territories is unaffected by climate change, but tuna fish, which is the main export product in the Fijian economy, disappear in other areas. This leads to an increase in the export price of the Fijian fisheries. The second alternative is the opposite: less fish in the Fijian territory, but no change outside. Consequently, the export prices remain as before, but the cost of sustaining the yield for Fiji increases. In the third alternative, the stocks of species caught by subsistence households increase, but the stock of tuna fish, which dominates the commercial fisheries, remains unchanged. The natural response to these scenarios would be good news if the export price increases, bad if the stock declines and good if the subsistence households catch more fish, but of little interest for those occupied with the national economy.

If analysing the alternatives within a macroeconomic model, the picture becomes quite different, however. We used a very simple macroeconomic equilibrium model with some properties we thought were important to characterise the Fijian economy. First, it was assumed that the substitution possibilities are constrained, as it is in many developing countries. Second, we included subsistence households in the model, assuming that they constitute a "reserve army" – in Marxian terms – for the labour force. Thus, if a shortage of labour occurs, the wages increase, and people from the subsistence households will try to apply for work. There is a cost attached to leaving the subsistence household, however, namely is the risk of getting unemployed. According to Harris and Todaro (1970), both an equilibrium wage and an unemployment rate appear under these assumptions.

Table 1. Percentage changes in main macroeconomic indicators at alternative scenarios of effects of climate change on fisheries in Fiji.

	(i) Higher market price	**(ii) Higher costs**	**(iii) Higher catch in subsistence househ.**
Gross national product	-0,1	-2,5	-0,6
Exports	33,5	15,2	-3,4
Production of commodities	-2,6	-3,2	-0,7
Capital owners' income	-188,2	-44,6	-5,6
Wages	12,5	1,4	0,4
Households' income	-1,3	-2,5	-0,6
No. of employees	2,2	-1,3	-0,6
Unempolyment	2,3	-1,4	0,3

Table 1 shows how some main macroeconomic indicators were affected. In case (i) the market price were increased by 10 percent. More fish is thereby exported, but the part of the commodity sector that processes fish for the home market will experience higher costs, and tend to turn to more labour intensive activities. Being a developing country, such a change is relatively painful. The inflexibility of the economy – or low elasticity of substitution – is one explanation. Another is that it becomes more difficult to make people leave the subsistence households, because they need to earn more to obtain the same quantity of food – measured in kg of fish – as before. A process of change under these circumstances therefore becomes costly because it requires a substantial increase in the wages. This leads to a squeeze of the capital owner's income, and results in a decline of the total income for the households. This reduces the demand for commodities and services, and GDP is actually lower after the value of fish increased than it was before.

The opposite case, alternative (ii), were analysed as one where the cost of fisheries increased. This corresponds to the assumption under which the changes in volumes of the input-output matrix earlier were considered: To catch the same amount of fish as before, one needs more labour, for example because they need to fish in more distant territories. To manage this, the wage has to be increased again. Again, the capital owner's income decreases, but less than in alternative (i) because total employment decreases even though the supply of labour from subsistence households increase when the wages increase. The increase in the value of exports is only a result of higher costs, since export is exogenous in the model.

The third case is presented to remind that although subsistence households are not integrated in the economy, it is not irrelevant to the macro economy what happens with them. In this case it becomes more difficult to attract people from these households to apply for work. Everything else being equal the effect is that the labour market is tightened, and the wages thereby increase. All the other indicators exhibit negative consequences.

This study is based on a overly simple model. In a dynamic perspective, for example, the flexibility will not constitute the same constraints as in a static model. The static perspective may apply to point out problems related to transformation to a changing climate, but not to estimate long-term costs. In the context of this presentation, however, the main point is to show that inclusion of economic relationships and market structures may give rise to some significant adjustments to conclusions drawn from what I have called sector studies, or from a simple and straightforward aggregation of such studies to the national scale. Among the advantages of linking focused sector studies to an aggregated level by framing the results into the macroeconomic perspective, I will mention the issue of adaptation, which has received a lot of attention in recent years. In my view, adaptation becomes less of a mystery when analysed by means of the well-known analytical tools provided by economics, than we sometimes see when adaptation is analysed on the basis of interviews of individuals from small groups of people.

5 Conclusions

Integrated models comprise a wide range of approaches to assess impacts of climate change, the various models emphasise different aspects of climate change. My impression is that one of the greatest challenges when developing integrated models with an economic point of reference is to draw as much as possible out of the available knowledge about effects of climate change, and at the same time provide as much insight from economics as possible. My suggestion to achieve this goal is, in short, to try to fit the results of sector studies into the framework of national accounting in order to prepare for a broad macroeconomic analysis. The economic analysis can, however, be considered a final step on a process that I believe provides useful and important information on the road to the final assessment, such as

a) The national accounting framework helps define a demand for information, a reference for an evaluation of the quality of knowledge about impacts and gives guidance to the interpretation of results from sector studies in the context of a national assessment.
b) Collecting information helps to get an overview of a very fragmented picture of results from various impacts studies, and it enables comparisons for the purpose of a national assessment
c) The results are put directly into a framework applicable for macroeconomic analysis, thereby enabling integration of related issues, such as climate policy, and explicit treatment of adaptation.