State of the art review: development-first modelling frameworks and approaches

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State of the art review: development-first modelling frameworks and approaches

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1. INTRODUCTION

It is not surprising that the current state of global affairs scores very poorly in terms of both development and sustainability criteria. This is partly a function of the traditionally slow evolution (maturation) of the definition of development and of the limitations and shortcomings of the modelling tools used to support policy decisions to date. A review of the critique of these definitions and tools can aid discovery of what is needed in new tools and approaches. The aim of this paper is to aid in the understanding of the nature of development-first modelling, to determine shortcomings of the current modelling tools in addressing development issues and to suggest avenues of potential improvement to be explored.

The paper commences with a review of the evolution of the definition of development. This is concluded with an overview of the current generally accepted development definition. Next, the relationship between development and climate change as policy objectives are discussed, followed by an in-depth review on the multiple dimensions of this relationship. Reviews of the status of traditional development modelling tools, as well as decision support tools used in the climate policy space, is then presented. The following section highlights emergent desirable modelling characteristics, as found in the literature. The section concludes with summaries of ideal model characteristics, of model characteristics to avoid and a mapping of ideal model characteristics to the most widely used operations research modelling tools. It is concluded that combinations of existing tools are needed to properly represent development issues.

2. THE EVOLVING DEFINITION OF DEVELOPMENT

Historically, according to Bologna (2008), the term development referred to the material and quantifiable growth of a country or a region’s economy, only. The development indicator of a given region was, thus, measured exclusively in economic terms, with no variable linked to environmental issues. As such, global and national development was, for many years, estimated based exclusively on the annual growth of gross domestic product (GDP) per capita (Ray, 1998). Economic growth was seen as the key to humanity’s well-being and, through such growth, it was assumed poverty would be overcome: as everyone floated higher, those at the bottom would be raised out of poverty (Hopwood, Mellor, & O’Brien, 2005). Economists often treated the terms economic growth and economic development as more or less synonymous (Barder, 2012).

In Owen Barder’s online presentation on development and complexity (Barder, 2012) he narrates the dawning of the recognition in economic theory that, in fact, economic growth alone is not necessarily sufficient to lead a country out of poverty. To paraphrase: initially, the Harrod-Domar growth model of the 1940s assumed that to make a unit of output, a combination of capital and labour inputs were needed. A firm could, thus, increase its output by increasing the amount of capital or labour used. Here, the economy was seen as the sum of all the firms within it, so to increase the output of the whole economy, either more capital or more labour was required. Since developing countries typically have surplus labour, it appeared evident that capital was the limiting factor in their growth trajectories.

In 1960, Walter Rostow published The Stages of Economic Growth, which claimed that development is a virtuous circle: when investment rises it means that the capital stock rises, hence output rises, leading to higher incomes and more savings.
Thus, greater investment in developing countries were thought to be the catalyst sparking higher capital stocks, enabling them to overcome the growth hurdle. Rostow’s model was hugely influential as a rationale for foreign aid in much of the 1960s and 1970s. It was thought that once the investment needed was known, the amount of foreign aid that is needed to fill the gap between domestic savings and the level of investment required could be calculated. Yet, poverty continued. Robert Solow introduced what is now known as the neoclassical growth model in the late 1950s. It introduced a third component, on top of labour and capital, which he called technical change. The next step in the evolution of economic growth models was based on the assumptions that the existing models correctly predicted the potential of each firm, and so of the economy as a whole, but because of a series of failures of policy, the country was not living up to its theoretical potential. In other words, bad government policies interfered with the proper functioning of markets, causing output to be lower than it should be. The Washington Consensus was formed to address this obstacle, but once it became clear in the 1990s that the Washington Consensus was not having the desired effect, the development community decided that the problem was not policies, but rather institutions. This has taken various forms, including large development aid spending on technical cooperation, institutional strengthening, and various other kinds of capacity building. If institutions are conceptualised as the structures that shape resource allocations and markets, and if market mechanisms are employed to tackle climate change, it follows that weak institutions restrict a country’s ability to employ an equitable and efficient approach to managing climate change (Stringer, et al., 2014).

Acemoglu and Robinson (2012) indicate that mainstream development practice today is built on the incorrect assumption that poor countries are poor because their rulers have mistaken views of how to run their country: they prevent markets from working properly and they tolerate corruption. Development cooperation is based on the notion that we should try to engineer prosperity by providing the right advice and by convincing politicians of what is good economics. The reason that this is incorrect, according to Acemoglu and Robinson (2012), is that poor countries do not have weak institutions because they do not know any better, but because it suits the powerful elite to run things this way. In other words, a country’s institutions are not an externally-provided factor of production, like labour or capital, but an internally generated result of the country’s politics. The governance agenda, like previous grand narratives of development, has also not lived up to its potential (Barder, 2012).

Despite having said all this, Barder (2012) continues to say that the last fifty years has been the most successful period in world history in terms of reducing poverty, increasing incomes, getting children into school, improving life expectancy, reducing hunger and malnutrition, and increasing access to clean water. The traditional economic models, however, still have a very hard time explaining why some countries experience rapid economic growth and what can be done to elevate a country out of poverty.

By the late 20th century, authors such as Opschoor (1998) started to question whether economic growth is compatible with concern for the environment and human welfare. Economists were calling for approaches to development that went beyond increasing per capita income alone (Gowdy & Salman, 2008). They argued that economic growth - based solely on the market - was unsustainable, and that human progress would be possible without economic growth (Schneider, Kallis, & Martinez-Alier, 2010). Haq’s work on the human development reports for South Asia (Haq, Human Development in South Asia, 1997) emphasised that, while economic growth is necessary for poor countries, it does not automatically lead to human development. Haq et al (1995) called for a pro-active role from the state to invest in human development, in order to ensure that the benefits from economic growth are distributed evenly. Similarly, Nussbaum (2000) called for a focus on distributive justice, that is: creating the conditions for the realisation of a set of central human capabilities.
To this end, Ray (1998) advocated that development also means eradicating poverty and malnutrition, increasing life expectancy, facilitating access to basic sanitation, drinking water and health services, reducing infant mortality, and increasing access to knowledge and schooling, amongst others. Sen (1999), in turn, defined development as the expansion of human freedoms (political freedom, available financial services, social opportunities, transparency guarantees, protection and safety). This implies that development requires the elimination of all “obstacles to freedom”, such as poverty, tyranny, lack of economic opportunities, systematic social deprivation, negligence of public resources, and repression. Thus, true human development would be “the expansion of people's freedoms and capabilities to lead lives that they value and have reason to value” (UNDP, 2011).

Policies based on this definition of development promise to be more effective than simply relying on aggregate income growth alone to improve the lives of the worlds' poorest (Gowdy & Salman, 2008). They also offer more flexibility in adapting to environmental changes and widely differing cultural worldviews. Gowdy and Salman (2008) postulate that with a focus on well-being, individual happiness and self-actualisation, the developing world may improve its human welfare position without emulating the environmentally destructive consumption patterns that drove past economic growth in the developed economies.

In recent times, it has become apparent that improving the status of women, particularly in rural areas, is of critical importance in development (Brody, Demetriades, & Esplén, 2008). Numerous studies have shown that educating and empowering women is the most effective way to achieve development goals such as increasing income, lowering fertility rates, and improving health indicators (Gowdy & Salman, 2008).

The Human Development Index (HDI) is a widely used, more complete measure of human well-being than GDP per capita. It measures three basic dimensions of human development: health, education, and income. The development of the HDI in 1990 spawned a number of related indices that go deeper in terms of measuring the notion of human capabilities (Gowdy & Salman, 2008). One such index is the capability poverty measure (CPM) which looks at three basic capabilities: nourishment and health, the capability of healthy reproduction, and female illiteracy. The CPM measure, for instance, showed that while 21% of the population in developing countries were below the income poverty line, 37% were below the minimum standard in terms of capability in 2007 (Womenaid International, 2007). This measure shows that economic growth by itself does not increase human development for the poor (Gowdy & Salman, 2008).

The modern concept of sustainable development is another result of the growing awareness of the global links between mounting environmental problems, socio-economic issues to do with poverty and inequality and concerns about a healthy future for humanity (Hopwood, Mellor, & O’Brien, 2005). This concept was born from the recognition that past growth models have failed to eradicate poverty globally (and within countries), as well as the fact that the standard patterns of growth also damage the environment upon which we depend (Hopwood, Mellor, & O’Brien, 2005). Brundtland (1987), recognising this failure, called for a different form of growth: “changing the quality of growth, meeting essential needs, merging environment and economics in decision making”. His approach requires an emphasis on human development, participation in decisions and equity in benefits. Social justice today, and in the future, is a crucial component of the concept of sustainable development (Hopwood, Mellor, & O’Brien, 2005).

Haughton (1999) usefully summarised the ideas of sustainable development in five principles based on equity; futurity (inter-generational equity); social justice (intra-generational equity); trans-frontier responsibility (geographical equity); people treated openly and fairly (procedural equity); and importance of biodiversity (inter-species equity).
The standard model for sustainable development is of three separate, but connected spheres, representing the environment, society and the economy, with the implication that each sector is, at least in part, independent of the others (Hopwood, Mellor, & O’Brien, 2005). This view allows for trade-offs between environmental and social issues, like whether it is acceptable that some pollution is incurred to increase growth, or that some pasture land is sacrificed for development of a park, or that jobs are traded for cleaner air, for example. These trade-offs indicate a continued conceptual divide between the environment and humanity. The reality is that humanity is dependent on the environment, with society existing within, and dependent on, the environment. The economy exists within society. Humans live within the environment and depend on it for survival and well-being; the environment cannot be ignored (Hopwood, Mellor, & O’Brien, 2005).

With the term sustainable development becoming a very popular phrase to coin, the US National Science Foundation’s Workshop on Urban Sustainability (2000) found that the term sustainability was “laden with so many definitions that it risks plunging into meaninglessness, at best, and becoming a catchphrase for demagogy, at worst. [It] is used to justify and legitimate a myriad of policies and practices ranging from communal agrarian utopianism to large-scale capital-intensive market development”. Although widely accepted, the concept of sustainable development still needs more scientific discussion to be useful for decision-making processes (Bolis, Morioka, & Sznelwar, 2014). Any study adopting the term should clearly defined what is meant by it.

3. THE CURRENT SCHOOL OF THOUGHT ON DEVELOPMENT

A possible way of understanding development is to define it as the maximisation of human well-being (Bolis, Morioka, & Sznelwar, 2014). Human wellbeing, in turn, is defined with reference to five components (Fischer, et al., 2014): basic materials for a good life, security, health, good social relations, and freedom of choice and action. This approach to development encompasses not only physiological, basic and tangible needs (quantitative needs), such as food and shelter, but also other more intangible needs related to well-being (qualitative needs), such as family, safety and higher education. This corresponds with Lee’s argument (2000) that: “sustainable development is an unashamedly anthropocentric concept”. The overall concern with respect to sustainable development lies in the search for solutions for mankind’s short and long term survival and well-being (Bolis, Morioka, & Sznelwar, 2014).

What characterises the latest models of development is the intention of linking purely economic aspects with social goals of welfare for the majority of society (Bolis, Morioka, & Sznelwar, 2014). Moreover, the environment is seen as a constraint to achieving sustainable development, because the limitations of natural resources have a direct impact on the economy and, ultimately, on society. As sustainable development is an anthropocentric concept, the aspect of nature that concerns sustainable development is the one that affects mankind’s survival and well-being (Bolis, Morioka, & Sznelwar, 2014).

Bolis et al (2014) developed a conceptual model, named Sustainable Development with an Axiological Perspective (see Figure 1), encompassing three dimensions: satisfaction of human needs (including social and economic aspects), natural resources (making explicit the Earth’s limitations) and a decision making perspective (from an axiological point of view). The model proposes that sustainable development can be seen as development aimed at improving the well-being of society as a whole (including future generations), enabled by an axiological perspective in decision-making processes, considering the limitations of environmental resources. At one extreme (individual and functionalistic drivers), the decision perspective is...
concerned with objective, rational, short term, restricted and problem-oriented issues. At the other extreme (axiological drivers), this perspective considers more subjective, emotional, long term, value-based, systemic and intergenerational aspects before reaching a decision. This latter decision perspective promotes initiatives that are based on social values, ethics, cooperation, equity and equality. A more detailed exposition of the axiological dimensions are provided in Table 1.

![Figure 1 Sustainable development with an axiological perspective](Bolis, Morioka, & Sznelwar, 2014)

<table>
<thead>
<tr>
<th>Axiological dimension</th>
<th>Low level of sustainable development</th>
<th>High level of sustainable development</th>
<th>Effort needed in each dimension</th>
<th>Effort needed for sustainable development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural resources dimension</td>
<td>No consideration of natural resources limitations</td>
<td>Long term consideration of natural resources limitations</td>
<td>Research, planning and implementation of processes and products that reduce the depletion of natural resources and, at the same time, can satisfy human needs.</td>
<td>Satisfy the human needs of society as a whole (also for future generations) beyond a minimum level, which is enabled by a collective and axiological paradigm for decision-making, considering the limitations of environmental resources.</td>
</tr>
<tr>
<td>Satisfaction of human needs dimension</td>
<td>No satisfaction of human needs achieved for society as whole. This means that, for at least part of society, minimum human needs are not satisfied.</td>
<td>Beyond a minimum level of satisfaction of human needs for everyone in the world</td>
<td>Ensure that everyone’s needs are achieved.</td>
<td></td>
</tr>
<tr>
<td>Decision paradigm dimension</td>
<td>Individual and functionalistic perspective</td>
<td>Collective and axiological perspective</td>
<td>Make decisions aimed at global optimum rather than local optimum results.</td>
<td></td>
</tr>
</tbody>
</table>

(Bolis, Morioka, & Sznelwar, 2014)

Essentially, Bolis et al (2014) claim that the concept of sustainable development can be represented in terms of three pragmatic questions: are the environmental limitations for present and future considered and ensured? Are the human needs of society as a whole met beyond the minimum proposed by the World Commission on Environment and Development (WCED) (1987)? Are positive and negative impacts for society considered in decision-making processes? Furthermore, Bolis et al (2014) state that sustainable development would be impossible in the absence of an axiological vision that considers the economic value integrated with the others.

Development is better thought of as a characteristic of the economic, social and political system, not simply the sum of the well-being of the people in it (Barder, 2012). In other words, development is not an increase in output by an individual firm; it is the emergence of a system of economic, financial, legal, social and political institutions, firms, products and technologies, which, together, provide citizens with the capabilities to live happy, healthy and fulfilling lives. Once
development is seen and treated as a system property, and not the sum of what happens to the people and firms in the economy, we can gain new insights into how development can be accelerated and shaped (Barber, 2012).

Lélé (1991) pointed out the social implications of sustainable development and advised academics and practitioners to realise that the origin of poverty and environmental degradation is not only economic, since structural, technological and cultural aspects are also contributing factors. There is a close relationship between sustainable development and social issues, such as education, health and poverty. This realisation evidences the need for understanding and managing the interdependencies between the elements of a society, since the consequences of decisions taken by some individuals can be perceived by others who were not even considered in the decision making process. Sustainable development implies changing the perspective from an individual to a collective driver in decision-making (Bolis, Morioka, & Szelwar, 2014). When development is defined as “enlarging people’s choices, capabilities and freedoms, so that they can live a long and healthy life, have access to knowledge, a decent standard of living, and participate in the life of their community” (Sen, Development as freedom, 1999), this demonstrates the multi-dimensional nature of poverty and development, and that we should be concerned with distributions of impacts and not just averages.

4. THE RELATIONSHIP BETWEEN DEVELOPMENT AND CLIMATE CHANGE

Linkages between climate change and development are increasingly recognised. Climate change is largely the result of human-induced greenhouse gas emissions that are driven by socio-economic development patterns, characterised through economic growth, technology, population and governance. These socio-economic development patterns, in turn, determine vulnerability to climate change and the human capacity for mitigation and adaptation. The impacts of climate change on human and natural systems, in turn, influence socio-economic development patterns and, thereby, greenhouse gas emissions (Klein, Schipper, & S, 2005).

Both the Human Development Report 2007/8 (HDR) (UNDP, 2007) and the World Development Report (WDR) 2010 (World Bank, 2010) are devoted to the connections between climate change and development. The reports both emphasize that climate change is an obstacle for development and the advancement of low-income countries. Furthermore, high levels of poverty and low levels of human development limit the capacities of poor households to manage climate risks; that climate change is drawing resources away from development; that high-income countries must reduce their emissions; and that developing countries still need massive expansions.

They differ, however, on what trade-offs they see and in how they interpret development (Gasper, Portocarrero, & St.Clair, 2013). In the WDR, climate change is placed in a subordinate relationship to development, from the outset. It uses the concepts of development and (economic) growth interchangeably. Damage is expressed in terms of GDP in the WDR. In contrast, the concept of development in the HDR centres on human development (i.e. human well-being and prosperity). This report discusses damage in terms of people’s quality of life and questions the dominant paradigm that equates development to unending economic growth.

The WDR argues that some climate change policies have co-benefits in terms of growth, and that climate change policy is not a choice between growth and the environment. It states that the two goals can be combined although it notes that particular patterns of consumption and production are dangerous. Development remains treated as economic growth, but it is recognised that new ways of growing have to be devised (Gasper, Portocarrero, & St.Clair, 2013). A fundamental
premise in the WDR is that economic growth is required to remove poverty. A second fundamental premise is that economic growth does not need to be slowed in order to avoid dangerous climate change. Both reports see fighting climate change and fighting poverty as interrelated (Gasper, Portocarrero, & St.Claire, 2013). According to the WDR, economic growth enhances the resilience of countries that are vulnerable to climate change. However, the report also states that current growth is not sufficient for three reasons. Firstly, growth is not fast enough, growth can increase vulnerability to climate hazards, and is not equitable enough to assure that the poorest people will be protected (World Bank, 2010). Hence, the report advocates growth along a low-carbon path, with adaptation measures to take care of the more vulnerable in low-income countries. Storm (2011) criticises the WDR’s almost exclusive focus on “win-win” techno-fixes, as it suggests that the structural shift to a low carbon path can be painless (i.e. without sacrificing growth and development).

5. MULTIPLE DIMENSIONS OF THE DEVELOPMENT AND CLIMATE CHANGE RELATIONSHIP

From the literature reviewed, there is clear consensus that multiple criteria (objectives) need to be considered when modelling for development, for climate change and, certainly, when modelling for both simultaneously. The question is what these multiple dimensions are. The most rudimentary objectives are the three overlapping spheres symbolising sustainable development, namely social development, environmental development and economic development. Further to this, the actors involved represent a large variety of sectoral interests, including agriculture, tourism and recreation, human health, water supply management, coastal management, urban planning and nature conservation, to name a few (Klein, Schipper, & S, 2005). The climate policy planning process is complicated by the sheer complexity of the linkages in terms of synergies and trade-offs between climate change-related policy goals and broader developmental policy objectives (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014).

5.1 Climate compatible development

Climate compatible development (CCD) has emerged as a new concept that bridges climate change adaptation, mitigation and community-based development (Stringer, et al., 2014). It is increasingly recognised that human development and economic growth in developing countries are threatened by the impacts of climate change and that efforts to mitigate climate change need to be compliant with the broader context of countries’ overall development trajectories. It is argued that the historical disconnect between climate change adaptation and mitigation activities is being questioned, as opportunities to simultaneously address adaptation, mitigation and development are beginning to be identified. These realisations have led researchers to coin the term ‘climate compatible development’ (CCD), defined as development that minimises the harm caused by climate impacts, while maximising the many human development opportunities presented by a low emissions, more resilient future (Stringer, et al., 2014; Suckall, Tompkins, & Stringer, 2014).

The concept of CCD offers a way to bring together climate change adaptation, mitigation and development such that individuals, communities and countries can access resources by embracing growth and elements of well-being (Suckall, Tompkins, & Stringer, 2014). It calls for institutional changes that allow the integration of climate change and development. At a minimum, it requires the mainstreaming of climate change into development policy and demands institutions to be built and strengthened to help reduce risks and move towards greater equity and efficiency (Stringer, et al., 2014). Progress towards CCD requires multi-stakeholder, multi-sector working and the development of partnerships between actors who may not otherwise have worked together.
5.2 Interdisciplinary interests

Since action on climate change touches upon a myriad of inter-related and multi-dimensional aspects of societies, economies and the environment, any climate policy response would require interdisciplinary analysis (Scriecui, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis, 2013). Integrative interface science can provide new insights that go beyond the sum of what can be learned from its disciplinary components (Strasser, et al., 2014). While historically environmental change has been investigated from the view of single disciplines, its complexity requires interdisciplinary research efforts.

5.3 Other issues to be considered

Additional development issues are gender inequality and the growing gap between the rich and the poor (Gowdy & Salman, 2008). Furthermore, within an urban context, cities in the developing world face a “triple challenge to sustainability” (Puppim de Oliveira, 2013). Firstly, those cities are growing rapidly and need to provide the urban infrastructure for the booming urban population. Secondly, there is a growing degradation of the local environmental quality, because of the lack of environmental safeguards. Thirdly, cities need to address both mitigation and adaptation to the increasingly damaging effects of climate change.

5.4 Poverty alleviating mitigation actions (PAMAs)

Poverty alleviation often disappears as an explicit priority in wider concepts like socio-economic, low-carbon, or sustainable development (Rennkamp & Wlokas, 2012). Mitigation strategies rarely directly address the fact that large parts of the population live below the poverty line. Development remains the main rationale for policy intervention, whereas poverty and mitigation need explicit prioritisation.

To effectively achieve both objectives, it is argued that the development goals need to be clear, timed and quantified; actions to reach those goals need to be analysed according to their feasibility and potential impacts on both mitigation and poverty; and the actions need to be chosen according to these findings (Rennkamp & Wlokas, 2012). Rennkamp & Wlokas (2012) developed a typology for poverty alleviation mitigation actions, presented in Figure 2.

Type 1 PAMAs are those interventions that have the objective to reduce emissions and address poverty at the same time. These interventions may use the same technologies as other types, but they are implemented in a pro-poor way. Type 2 PAMAs would be mitigation actions without any pro-poor incentives and subsidies. Type 2 concentrates on where mitigation potential is high, which tends not to be among the poor (since emissions are low in absolute terms). Type 3 PAMAs represents conventional actions for poverty alleviation that focus primarily on poverty reduction and do not have significant mitigation potential. Emissions reductions might be a side effect. Type 4 PAMAs are ineffective actions, which fail in reducing either poverty or emissions, or conventional actions without an explicit focus on poverty alleviation and limited mitigation impacts.

Michaelowa and Michaelowa (2007) mention that despite over 7% of aid flows being spent on greenhouse gas emissions mitigation, the contribution of emissions mitigation projects to the central development objective of poverty reduction as specified in the Millennium Development Goals (MDGs) is limited. Rural renewable energy provision in poor countries has a high impact on poverty, but a low impact on greenhouse gas emissions. Moreover, mitigation activities in developing countries provide politicians in industrialised countries with a welcome strategy to divert the attention of their...
constituencies from the lack of success in reducing greenhouse gas emissions domestically (Michaelowa & Michaelowa, 2007). It is interesting to note that countries that are achieving an improvement of human development from a low level, are unlikely to increase their energy consumption substantially. Only at a level where the middle class expands rapidly, does energy consumption and greenhouse gas emissions soar.

<table>
<thead>
<tr>
<th>GHG REDUCTION POTENTIAL</th>
<th>POVERTY ALLEVIATION POTENTIAL</th>
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<tbody>
<tr>
<td>High</td>
<td>Type 1: Poverty alleviating mitigation action: Both poverty and mitigation are the main drivers of the action.</td>
</tr>
<tr>
<td>High</td>
<td>Type 2: Conventional mitigation action: Purely climate-driven mitigation action without explicit focus on poverty (and possible opportunity cost)</td>
</tr>
<tr>
<td>Low</td>
<td>Type 3: Conventional intervention for poverty alleviation, with no explicit focus on reducing emissions (and possible increase in emissions)</td>
</tr>
<tr>
<td>Low</td>
<td>Type 4: Failed/low impact mitigation action, failed poverty action, conventional industrial/economic/ environmental policy without explicit focus on mitigation and poverty</td>
</tr>
</tbody>
</table>

(Rennkamp & Wlokas, 2012)

Figure 2 Typology of poverty alleviation mitigation actions

It is argued that while there are valid reasons for long-term collaboration with emerging economies on greenhouse gas mitigation, there should be a separate budget line for such activities to avoid obfuscation of a decline of resources aimed at poverty alleviation (Michaelowa & Michaelowa, 2007). Questions that arise are whether development assistance allotted to climate policy should be considered as a genuine part of development aid, and whether it could possibly help to achieve development objectives unachieved so far by classical development cooperation? Or has it been introduced as a substitute, diverting resources from the core development objectives? Does development assistance allotted to climate policy really promote development, or is it primarily used by industrialised countries to reach their own climate policy objectives?

In a game theoretical model, Caparrós and Pereau (2005) assess the interaction between mitigation and development assistance. They find that increasing mitigation reduces the official development assistance (ODA) level in the long run, while short run dynamics might lead to a transitional increase in both mitigation and ODA, for an initial time period. As climate related activities are a significant, increasing and potentially unrestricted part of ODA, they should be geared towards the same objectives. Development objectives have been clearly defined and codified in the MDGs, therefore, when considering the role of climate policy within ODA, the most obvious test it has to pass is whether it contributes to the achievement of the MDGs. Looking at the long list of MDGs and targets, the link to climate policies is obvious at first glance only for goal seven, target one, but not so much for any other objective (Michaelowa & Michaelowa, 2007). However, when considering each of the MDGs carefully, one does indeed discover many ways in which climate policy related activities may help to reach the goals listed. Doing justice to the MDGs is a matter of setting priorities for those policies that will most efficiently achieve these goals. For instance, when it comes to the objective of universal primary education (goal two), one can construct an impact chain from electrification of a community, which results in improved learning, lower drop-out rates, and finally in higher enrolment. Yet the most efficient way to achieve universal primary education is certainly not via electrification of rural schools and households. Other measures, such as an increased supply of teachers, a reduction of
repetition rates or the provision of school meals will be far more effective. Similarly, for all other goals except goal 7, climate change related activities would not usually be considered as having the highest potential impact on poverty. All in all, the available evidence shows that only few areas exist in which climate and development priorities truly overlap (Michaelowa & Michaelowa, 2007).

5.5 Synergies and trade-offs

Synergies in climate policy are created when measures that control atmospheric greenhouse gas concentrations also reduce adverse effects of climate change, or vice versa. Such measures have ancillary benefits, which produces win–win situations (Klein, Schipper, & S, 2005). It is, however, doubtful that sufficient opportunities for synergies can be identified to achieve the levels of mitigation and adaptation deemed required. Even for those opportunities that are identified, it is unclear whether they represent a wise investment in terms of the mitigation and adaptation benefits accrued. The net effect of investing in synergetic measures – in terms of reducing damages – may well be smaller than when half the money is invested in more efficient mitigation options and the other half in more efficient adaptation options (Klein, Schipper, & S, 2005). It is, therefore, encouraged to seek ancillary benefits of mitigation and adaptation outside climate policy (such as development), as long as it is recognised that these are different for the two options. To determine which mix or mixes of policies and actions are justifiable, some multi-criteria framework needs to be designed with which one can capture, quantify and compare the direct and ancillary effects of implementation on each of these (and possibly other) criteria.

Climate co-benefits have been identified by various organisations as win-win opportunities to tackle climate change with other positive outcomes (Puppim de Oliveira, 2013). The co-benefits approach is especially important for developing countries, which have to overcome many challenges simultaneously with limited human capacities and economic resources. That is where much progress can be made, as these countries are still in the early process of development and can avoid many unsustainable paths of the so-called developed countries.

The complexity of quantifying co-benefits has implications for the development of an assessment tool or methodology for policy making that could be used broadly. There is a trade-off between quantification and generalisation of a methodology or tool to assess co-benefits (Puppim de Oliveira, 2013). Precise quantification requires a tool that will be difficult to use for all policy-makers from differing levels of technical expertise. This would limit its applicability and consequently its use. More quantification also means more data requirements. This would be costly and time consuming to apply too, because large amounts of data have to be collected and input into the system before the quantification tool can be used. Such a tool may not be viable in the context of many developing countries or in the case of small initiatives with limited resources.

A systems approach is needed to account for intended and unintended consequences of actions (Thornton & Comberti, 2013). Adaptation and development planning that considers both the full range of adaptation pathways and critical processes of transformational adaptation offers the best opportunities for achieving synergies between adaptation, mitigation and development.

The ideal when trying to model various objectives subject to trade-offs and synergies, is to maximise positive reinforcement, whilst minimising negative reinforcement. Further to this, it is important to note that in climate change modelling, the focus is on efficiency, whereas in development modelling, the focus should be on effectiveness. Where efficiency is high, but effectiveness is not achieved by a measure, the measure will not be successful in bringing about change.
5.6 Finding the optimal adaptation-mitigation ratio

The United Nations Framework Convention on Climate Change (UNFCCC) identifies two options to address climate change: mitigation of climate change by reducing greenhouse gas emissions and enhancing sinks, and adaptation to the impacts of climate change (Klein, Schipper, & S, 2005). Mitigation comprises all human activities aimed at reducing the emissions or enhancing the sinks of greenhouse gases, such as carbon dioxide, methane and nitrous oxide. Adaptation, in the context of climate change, refers to any adjustment that takes place in natural or human systems in response to actual or expected impacts of climate change, aimed at moderating harm or exploiting beneficial opportunities.

The question has arisen as to exactly how much mitigation and adaptation would be optimal, and in which combination. The optimal mix of response options will vary by country and over time, as local conditions and costs change. Striking the balance will be particularly challenging, because of some unique characteristics of the problem: long time horizons, non-linear and irreversible effects, the global nature of the problem, social, economic, and geographic differences amongst affected parties, and the fact that institutions needed to address the issue have only partially been formed (Klein, Schipper, & S, 2005). It is claimed that there is no single optimal mix of mitigation and adaptation. A more useful question, thus, would be (Klein, Schipper, & S, 2005): what would constitute a mix that is justifiable from a social, environmental and economic perspective; which elements would be part of such a mix and how it can be determined?

Progress towards climate change aware regional sustainable development is affected by actions and decisions at multiple spatial scales and governance levels, and equally impacts actions at these scales (Daniell, Costa, Ferrand, Kingsborough, Coad, & Ribarova, 2011; Klein, Schipper, & S, 2005). Many authors and policy practitioners consider, therefore, that decisions over policy, mitigation strategies and capacity for adaptation to climate change require construction and coordination over multiple levels of governance to arrive at acceptable local, regional and global management strategies. Multi-level decision-making processes are considered to be a growing necessity, as resources required for control over decision making and action implementation are increasingly distributed between actors with different sectorial interests, who have responsibilities for decisions at different administrative levels of governance (Daniell, Costa, Ferrand, Kingsborough, Coad, & Ribarova, 2011). This means that it is increasingly rare that any one government department, private company or interest group has sufficient power and resources to implement its policy decisions without the help of other groups.

5.7 Multiple levels of decisions and stakeholders

Progress towards climate change aware regional sustainable development is affected by actions and decisions at multiple spatial scales and governance levels, and equally impacts actions at these scales (Daniell, Costa, Ferrand, Kingsborough, Coad, & Ribarova, 2011; Klein, Schipper, & S, 2005). Many authors and policy practitioners consider, therefore, that decisions over policy, mitigation strategies and capacity for adaptation to climate change require construction and coordination over multiple levels of governance to arrive at acceptable local, regional and global management strategies. Multi-level decision-making processes are considered to be a growing necessity, as resources required for control over decision making and action implementation are increasingly distributed between actors with different sectorial interests, who have responsibilities for decisions at different administrative levels of governance (Daniell, Costa, Ferrand, Kingsborough, Coad, & Ribarova, 2011). This means that it is increasingly rare that any one government department, private company or interest group has sufficient power and resources to implement its policy decisions without the help of other groups.
5.8 Temporal dimensions for decision-making

Another vertical axis to consider is the effects of decisions on both the short term and the long term. The axiological model developed by Bolis et al (2014) also supports this notion. In developing countries, climate change is often perceived as a long term issue, where other challenges, including food security, water supply, sanitation, education and health care, require more immediate attention (Klein, Schipper, & S, 2005). Suckall et al (2014) find that certain responses to stressors in this domain resemble coping strategies instead of adaptation strategies, as they provide short term relief, but in the long term may negatively affect development goals. These coping strategies lead to high carbon pathways, and generate worsening development conditions that serve to undermine long term socio-economic development (Suckall, Tompkins, & Stringer, 2014).

6. THE STATUS OF TRADITIONAL MODELS OF DEVELOPMENT

During the last quarter of the twentieth century, economic theory and policy came to be, for the most part, based on the micro-foundations principle (Gowdy & Salman, 2008). That is: the proper way to examine macroeconomic problems is to use the assumptions and concepts developed to study the behaviour of individuals and firms. This fosters the idea that development is a gradual process of firms becoming more productive, and household incomes gradually rising, thus creating the opportunities which enlarge people’s choices, capabilities and freedoms (Barder, 2012). According to many observers, the micro-foundations approach to economic theory has been in a state of crisis for some time now (Gowdy & Salman, 2008). Many of the standard tools of economic analysis - for example, competitive general equilibrium (CGE) and the theoretical system that supports it - have fallen into disfavour in analysing global issues involving uncertainty and irreversibility.

The standard models of climate change and economic development have been criticised for an over-reliance on general equilibrium theory (Gowdy & Salman, 2008). One area of concern is the use of per capita GDP in these models as an indicator of social welfare. Frey and Stutzer (2002) point out that economic texts often do not even discuss the meaning of utility, but rather merely assume that utility is equivalent to income and that more income makes a person happier. There are further disagreements over whether market-based growth can and should be the leading tool to address both poverty and climate change (Gasper, Portocarrero, & St.Clair, 2013). According to traditional economic theory, the economy has an equilibrium point to which it naturally progresses, which has raised major concerns as to its ability to meaningfully represent socio-economic realities (Beinhocker, 2007).

The dominant underpinning policy approaches used to manage climate change through broader socio-economic processes are often grounded (at least in part) in the neoclassical economic paradigm, which is broadly concerned with creating optimal resource allocation (Stringer, et al., 2014). A survey of the literature by Scricciu et al (2013) revealed that, out of 30 climate-economy models considered in seven widely-cited model comparison studies in the field of climate mitigation economics, only one model adopted a non-optimisation and non-equilibrium simulation approach to the issue. This typically requires the internalisation of environmental externalities into the market mechanism, through the use of, e.g. taxes, insurance and so on. Despite the international support for these kinds of market-based approaches, they tend to overlook the inefficiencies in resource allocation in developing countries attributed to weak institutional bases, as well as equity concerns linked to human well-being. The possibility of policy-induced green economic growth occurring at greater rates than those of business-as-usual or brown growth is typically ruled out by default in standard economics (Scricciu, Belton, Chalabi, Mechler, & Puig, 2014). This results from the use and assumption of representative-agent utilitarianism,
perfectly rational and self-interested behaviour, competitive general equilibrium theory, and optimisation techniques, whilst neglecting strong kinds of uncertainty, such as fundamental uncertainty (Dequech, 2008). In addition, optimal growth and equilibrium models function on the descriptive representative-agent assumption, which has been shown to cause an intrinsic (regressive) distributional bias in favour of the rich, and, thus, produce questionable optimal emissions recommendations (Scott & Davis, 2013). This constitutes a serious issue for social well-being, should climate action follow in the footsteps of such recommendations (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014).

There are, however, some recent developments in the CGE literature that accommodate the suboptimal behaviour of economic systems, such as the dynamic stochastic general equilibrium (DSGE) models (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014). These allow for suboptimal macro-economic behaviour, for instance the existence of involuntary unemployment (Kemfert, 2003). Nonetheless, few of these models have been applied to climate policy analysis, and, furthermore, they still assume that economies revert to market equilibrium conditions in the long run, which may not necessarily be the case.

Scrieciu et al (2014) state that traditional economic approaches are, arguably, ill-suited to offer good practice evaluation standards in respect of technological innovation, learning, dynamics and feedbacks; in formulating no-regrets options for mitigation and adaptation; in performing monetary valuation and assessing non-marketed impacts; in discounting future costs and impacts; in dealing with the time horizon of the analysis; and in accounting for risk and uncertainty.

7. DECISION SUPPORT MODELS FOR THE CLIMATE CHANGE PROBLEM

The stern insistance on the traditional economic (static and inter-temporal) optimisation and equilibrium theory has resulted in the dominance of a particular methodology for framing thinking and decision making in a large range of economic, social and environmental problems, including that of climate change – namely, the cost-benefit analysis (CBA) approach (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014). This approach compares the marginal costs of a mitigation or adaptation policy with the marginal benefits associated with the climate change that is avoided (including ancillary benefits), in order to identify the most beneficial (economically efficient) policy response (Dessler & Parson, 2006). Marginal, in this context, refers to the additional cost that will be incurred by the current emission to the atmosphere of one unit of greenhouse gas. CBA is well suited to analyse the pure financial feasibility of investment projects or efficient financial allocation decision making, where future financial flows may be readily identified and predicted, monetary aggregation is justifiable, and price setting clear-cut. Unfortunately, the standard CBA approach has major limitations when applied to the long-term, multi-dimensional, challenging problem of climate change (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014). This is in part because of “the incredible magnitude of the deep structural uncertainties that are involved in the climate change analysis” (Weitzman M. , 2009).

Within the context of dealing with climate change with highly complex features, such as future time, doubt, and irreversibility, standard CBA falters and implementing it is no longer merely a technical task, because many subjective choices are due (Verbruggen, 2013). Several non-market impacts, or externalities, are difficult (and even unethical) to cost, and as a result do not feature in the evaluation of costs and benefits (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014). There are also fundamental concerns about the appropriate discount rate to use in CBA analysis, as CBA studies are highly
sensitive to the choice of discount rates, reducing the robustness and reliability of their findings and estimations (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014).

On the positive side, alternative economic approaches and models are being developed and increasingly used in the analysis of and decision support for climate action (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014). Such alternatives include cost-effectiveness analysis (CEA), robust decision making approaches (RDMA) and multi criteria decision analysis (MCDA). Table 2 provides a summary of these four different decision support techniques, their pros and cons, and their suitability for being applied to climate change policy planning.

CEA is a technique that can be used to identify least-cost options to meet a certain, pre-defined or fixed target or policy objective. For example: in the case of mitigation, the reduction in greenhouse gas (GHG) emissions levels to particular levels at different periods in time (Haines, et al., 2009).

RDMA methods have seen limited use in the area of climate change to date, though they are receiving increasing attention. RDMA essentially provides an analytical decision support framework for situations characterised by high uncertainty (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014). Within this context, uncertainty refers to the lack of agreement among interested parties, lack of analytical approaches to analyse the issue at hand, lack of knowledge about the state and trends of the parameters affecting that issue, or any combination of these. Rather than attempting to make decisions on the basis of predictions of future states in variables of interest, RDMA attempts to identify the full range of plausible future states and, on that basis, make decisions that are robust across as wide a range of future states as possible. A key aspect in RDMA is the notion of iteration and repeated analysis with modified assumptions and scenarios (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014). Two main families of RDMA approaches can be distinguished; static and dynamic. The latter take better account of cost-effectiveness considerations, but are much more demanding in terms of human capital and data collection capacities. Methods are nevertheless rather complex and often require the use of advanced statistical and mathematical tools.

Alternatively, MCDA is a tool that can accommodate both quantitative, as well as qualitative criteria simultaneously. It also integrates well with stakeholder participation in developing the list of criteria to be assessed.

Table 2 Summary of recent decision support techniques

<table>
<thead>
<tr>
<th>DECISION SUPPORT TECHNIQUE</th>
<th>DECISION CRITERION</th>
<th>ADVANTAGES</th>
<th>CHALLENGES</th>
<th>APPLICATION</th>
<th>REFERENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBA*</td>
<td>Optimality; maximise the money value of social welfare</td>
<td>Rigorous framework based on aggregating costs and benefits to a single number; readily compares and prioritizes options based on net monetized benefits</td>
<td>All costs and benefits must be monetized and aggregated; difficulty in representing plural values; takes no account of uncertainty; assumes ‘marginal’ changes</td>
<td>Well-specified interventions with tangible price-centred benefits and costs</td>
<td>Pearce et al (2006); Boardman et al (2010); Dietz and Hepburn (2013)</td>
</tr>
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State of the art review: development-first modelling
State of the art review: development-first modelling

8. EMERGENT DESIRABLE CHARACTERISTICS OF MODELS OF DEVELOPMENT

8.1 Systems modelling approach

A new type economic analysis is needed to provide answers by not only focusing on cost-effective strategies, but by also ensuring that any climate action is equitable and compatible with context-specific development goals and priorities (Scrieciu, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis, 2013). To some extent, this is already occurring with mainstream economic thinking on climate change shifting from a single-discipline focus (such as cost-benefit analysis, preferred by traditional economists), to a new, inter-disciplinary risk analysis approach (Scrieciu, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to
consider in climate policy analysis, 2013). This approach requires the development of a complex global system of energy-environment-economy interactions, with credible, endogenous dynamics of output, emissions, prices, and incomes.

An example of systems modelling in this domain is Tang et al.'s income-climate trap model (Tang, Petrie, & Rao, 2009). They developed the income-climate trap model to explore the multi-directional interaction between the economy, climate change and life expectancy. It is suggested that these interactions can give rise to either a virtuous cycle of prosperity or a vicious cycle of poverty. The climate (and geography in general) affects not only health, but also economic development, especially in terms of agricultural production. At the same time, income (alongside other elements of development) is vital in determining health status. Therefore, the climate-life expectancy relationship should not be examined in isolation from the income-health relationship. Additionally, while the climate can adversely affect production and health, income and economic development can in turn provide protection against these adverse effects (Tang, Petrie, & Rao, 2009). The climate impact is multi-dimensional - a good climate for life expectancy may not always be good for productivity, and vice versa.

Figure 3 provides a schematic representation of the theoretical model that demonstrates the possible underlying relationships between climate, income (used here as a proxy for development) and life expectancy (serving as proxy for health status).

In Figure 3, path (a) indicates the direct effect of climate on life expectancy, which could come from the spread of tropical diseases or natural disasters or the availability of rainwater or extreme temperatures. Path (b) indicates the direct effect of climate (e.g. rainfall or drought) on production, especially on agriculture, and thus on income. At the global level, economic activities (measured by income) may affect the climate in the long-run (greater than 50 years). But, at the national level and in the short-to medium term, it is reasonable to assume one-way causality from climate to income (Tang, Petrie, & Rao, 2009). Path (c) indicates the direct effect of income on life expectancy. Economic development can influence life expectancy positively via the provision of shelters, health services, education, law and order, and infrastructure, and
negatively via poor diet and lifestyle choices, pollution, workplace hazards and stress. On the contrary, path (d) indicates that life expectancy can influence economic growth. First, better health will raise labour participation and productivity.

Second, a higher life expectancy will lower the subjective discount rate of non-myopic individuals, encouraging saving and long-term investments in both physical and human capital. These effects, via both labour and capital markets, will stimulate technological progress and eventually lead to higher income growth (Tang, Petrie, & Rao, 2009). Path (e) indicates the indirect effect of income on life expectancy, via moderating the impact of climate on life expectancy. Countries with higher incomes or adequate foreign aid can afford more resources to alleviate the adverse effects of climate on life expectancy, such as using air conditioners or heaters during summers and winters, developing early warning systems for natural disasters, using vaccines against tropical diseases, or improving sanitation to control the spread of infectious diseases.

Finally, path (f) indicates that income can also moderate the adverse impact of climate on income itself. For example, countries with sufficient resources can build storm drainage networks against floods and water-recycling systems against droughts.

Building this model, consider two continents: Favourable and Unfavourable with respect to climatic conditions (Tang, Petrie, & Rao, 2009). Suppose initially the income levels of both continents are roughly equal at the subsistence stage. If climatic conditions in continent F are more favourable for agricultural production, e.g. F has ground frost that helps control plant and animal diseases, then this will lead to a higher income level. If the climatic conditions in continent F are more favourable for health, e.g. ground frost can kill organisms that transmit diseases to human, it will also result in a high income level through the mechanism of path (d) described above. In either case, continent F will have more resources available to reduce mortality risks, including those related to climate. A higher life expectancy will, once again via path (d), stimulate growth, and the higher income will further alleviate the residual adverse effect of climate on life expectancy (probably at a diminishing rate). A virtuous cycle is thereby formed. Furthermore, as the manufacturing and service sectors grow relative to the agricultural sector, production, and thus development in this context, will be less susceptible to climatic factors. Hence, as income grows, the importance of climate as a determinant of life expectancy will reduce.

For continent U, on the other hand, the less favourable climate means that its initial growth is slow. Without sufficient resources, it cannot afford to develop technology to shield its population from the adverse climate. As long as the life expectancy is low, people have less incentive to save and make long-term investments. Consequently, the income levels remain low and the continent remains vulnerable to the adverse climate. A vicious cycle is thus formed. Moreover, since the economy is dominated by agricultural production at this development stage, the income level is closely tied to climate. Thereby, climate will have a much bigger impact on life expectancy in continent U.

This example, though it may appear archetypal, serves to highlight how the simple feedback mechanism of the moderation effect of income on life expectancy against adverse climate conditions could potentially give rise to vastly different development outcomes (Tang, Petrie, & Rao, 2009). Based on the income-climate trap model, three testable hypotheses can be formulated (Tang, Petrie, & Rao, 2009). H1: Income can moderate the adverse effect of climate on life expectancy. H2: As income grows, climate will become less important as a determinant of life expectancy. H3: Climate is more important as a determinant of life expectancy for African countries than for non-African countries.

It can be concluded that climate change and development are inextricably intertwined, although the politically dominant theme of the two in a country will, to a large extent, be dependent on the development level and social context of that country.
8.2 Recognition of complex adaptive systems

In a complex economy and society, there are a large number of adaptive processes going on (Barder, 2012). People adapt - their tastes and habits and perhaps even their psychology and physiology change, in response to changes in their circumstances. Similarly, products, firms, technologies, and institutions all adapt and evolve. There is a constant process of adaptation, leading to changes in physical technologies, people’s behaviour, business plans and firms, social institutions, and the environment in which society and the economy reside (Barder, 2012). What is more, all of these elements are changing in response to each other.

The economy and society can, thus, be considered as being composed of a rich set of interactions between very large numbers of adaptive agents, all of which are co-evolving. These are the classic circumstances which create what physicists and biologists call complex adaptive systems (Barder, 2012). Part of the complexity encountered is owed to the fact that the economy, and interactions between key components of the economy, are seldom linear – non-linear systems abound.

Barder (2012) lists five important features of complex adaptive systems. First, they are difficult (or even impossible) to predict in detail. Second, it is, however, possible to make broad brush predictions about the system as a whole. As an example: while it is not possible to say whether there will be a thunderstorm on a particular day in London, it is possible to roughly describe what the weather will be like in London in July. Third, complex adaptive systems have emergent properties, i.e. there are patterns within the system which are not specifically linked to any individual agent within it. Importantly, Barder (2012) states that development, itself, is such an emergent property of the economy. Fourth, complex adaptive systems tend towards greater complexity. This is quite the opposite of most economic models, which tend towards simplicity and equilibrium. And fifth, these systems do not tend towards an equilibrium. Generally, the global patterns in a complex adaptive system tend to be stable for relatively long periods of time and then unexpectedly make fast, large changes. The absence of equilibrium can be attributed to the ongoing process of co-evolution (Barder, 2012).

Each agent in the complex adaptive system of the economy is evolving in the light of the context it faces. The evolutionary pressures are normally driven by other agents within the economy, which are, themselves, adapting and evolving. This combination of co-evolution and the existence of time-lags means that there is no equilibrium towards which the economy as a whole is moving.

What this recognition that the interactions between the economy, the environment and society constitute a complex adaptive system implies for modelling and policy making, is that it is very difficult to design and engineer solutions in such a system (Barder, 2012). At the level of specific improvements, evolutionary processes often outperform design. At the level of the system as a whole, the non-linear dynamics mean that it is generally impossible to predict what will happen as a result of any particular change. Again, this makes engineering solutions almost impossible. What this means is that, instead of trying to replace evolutionary processes (of adaptation and complexity), the aim should be to try and harness them.

Another conclusion drawn by Barder (2012) is that the idea of greater experimentation as a component of the development process should explicitly be embraced. He proposes that the most promising way to grop towards improvements in systems with emergent properties is to make small changes, see what happens, and then adjust. Additionally, it is suggested to start by directing more effort towards the things that can be controlled.

To summarise, Barder (2012) states that development policy should not try to look for missing ingredients or try to engineer poverty reduction. Rather, it should try to harness the strength of adaptation and complexity. It should embrace experimentation and look for ways to nurture adaptation and evolution which may help to bring about change in ways
which, not only accelerate evolution, but also shape it to be consistent with social values and goals. Simulations of the evolutionary processes, complex interactions and individual agents’ roles are desirable modelling components.

**8.3 Integrated modelling approach**

Integrated thinking is required on the environmental challenges faced by humanity (Fischer, et al., 2014). By its nature, research in this field requires multidisciplinary collaboration, for which integrative conceptual frameworks are useful to make sense of complexity (Ostrom, 2009). Kelly et al. (2013) distinguish the five types of integration: integrated treatment of issues, integration with stakeholders, integration of disciplines, integration of processes and integration of scales of consideration. Kragt et al. (2013) present challenges of integrated research and modelling of environmental systems, focussing on the modellers’ role in structuring integrated research projects. They differentiate between technology integration, knowledge integration and team integration.

Where research on climate change impacts is based on integrated modelling, the joint model development and interface design are core elements of integration. Such integration can be regarded as a mutual learning and negotiation process, where understanding continuously develops, often unpredictably, and it is highly dependent on how it is organised (Strasser, et al., 2014). One major characteristic of such coupling processes is recursivity: the outcome of a certain model run can stimulate the repetition of the numerical experiment with modified settings. Similarly, in the development of the modelling concept, recursivity can be very important in continuously improving the model’s quality.

Communicative integration is seen as the differentiating between and linking of different linguistic expressions and communicative practices, aimed at developing a common discursive practice, in which mutual understanding and communication is possible (Strasser, et al., 2014). This includes the clarification of common terms and, if necessary, the creation of new ones. Social integration, in turn, addresses the need for differentiating and correlating the interests and activities of involved parties, as well as the clarification of roles, and the building of teams and leadership (Strasser, et al., 2014). It further includes organisational aspects which provide practical conditions for integration. Cognitive integration relates to the differentiation and linkage of different knowledge bases, to create mutual understanding with respect to theoretical concepts and methods applied in the disciplines involved. Modes of research that foster the linkage between knowledge production and societal transformation are promising alternatives to more traditional research that focuses only on scientific knowledge production (Strasser, et al., 2014).

The need for integrated models supports the notion that system-wide effects need to be considered, as an intervention in a particular sector may reverberate across the entire economy (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014).

**8.4 Consideration of behavioural aspects**

Experimental results from behavioural economics, evolutionary game theory and neuroscience have firmly established that human choice is a social, not self-regarding, phenomenon (Gowdy & Salman, 2008). Two broad principles have emerged from the literature: human decision making cannot be accurately predicted without reference to social context, and regular patterns of decision making, including responses to rewards and punishments, can be identified, both within particular cultures, and across cultures.

The existence of pure altruism is not recognised in the traditional economic framework and this omission may seriously affect policy recommendations (Gowdy & Salman, 2008). Altruism implies that a wider range of effective policies may be
available to encourage cooperation and mutual aid for the common good. Altruistic punishment means punishing others who violate social norms, even at cost to oneself. Henrich et al. (2006) argues that cooperation and altruistic punishment go hand in hand. People are willing to make sacrifices for others when they are assured that others (free riders) can be punished if they take advantage of altruistic behaviour. The existence of punishing and sanctioning mechanisms can ameliorate two related problems in resource management (Killingbach, Bieri, & Flatt, 2006): free-riding and the tragedy of the commons (i.e. individuals acting independently and rationally according to each one’s self-interest, behave contrary to the whole group’s long-term best interests, by depleting some common resource).

With regards to altruistic punishment it is a widespread finding that, in humans as well as in other members of the animal kingdom, a sense of fairness is an important determinant of behaviour and decision-making (Gowdy & Salman, 2008). The behavioural findings regarding trust and fairness have significant consequences for climate and development policy. The policy debate surrounding both these issues has centred on fairness, both in terms of intergenerational and cross-cultural equity. The finding that people are loss-averse (i.e. people place a higher value on losing something they have, than they do on gaining something they do not have) is well established (Knetsch, 2005). This loss aversion implies that if economic policies are to hold true to this theory of human preferences then these policies should err on the side of caution. This is especially true when it comes to placing values on environmental features. Estimating the value of environmental quality to future generations almost always involves losses (loss of climate stability, non-renewable resources, clean air and water) (Gowdy & Salman, 2008). Loss avoidance is particularly important in vulnerable communities where the consequences of loss may be very large. These and other behavioural regularities should be considered carefully while developing climate change adaptation strategies. It is postulated that policies building on types of behaviour conducive to cooperation, placing less emphasis on material possessions, and recognising the necessity of shared sacrifice, are more likely to be successful in meeting the climate change challenge (Gowdy & Salman, 2008).

8.5 Low regrets policy development

Scrieciu et al. (2014) call for a different version of economics, which embraces an interdisciplinary perspective, pluralism, and combines objective assessments with value judgements. Human preferences, ecological properties, and technological possibilities cannot be valued solely through utilitarian lenses and standard welfare economic theory, but, instead, require a conceptual pluralism approach to the concepts of value, value systems, and valuation (Farber, Costanza, & Wilson, 2002). Furthermore, standard economics techniques tend to neglect important ethical questions and overlook the variability in value judgements across population and across time (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014).

The IPCC (2012) suggests that an approach grounded in low regrets strategy formulation may usefully provide for more robust mitigation and adaptation strategies. Such an approach has high potential for reducing long-term risk and at the same time provide for short-term benefits in terms of, for example, reducing vulnerabilities today in the case of adaptation. As one consequence, the IPCC report suggests to focus more strongly on iteration, processes, learning and innovative thinking, which are attributes that can be closely aligned with a multi-criteria approach (IPCC, 2012).

8.6 Use declining discount rates

According to Ackerman (2009), there are four fundamental requirements for an adequate economic framework on climate policy. The first requirement is judgement regarding the importance of current versus future generations, with implications for discounting. The second requirement is the incorporation of multi-dimensional, often non-monetary impacts (again rendering cost-benefit analysis problematical). Thirdly, it is required that the problems of catastrophic risks and irreducible
uncertainty are recognised, leading to a precautionary approach to policy. Finally, the fourth requirement is an understanding the nature of implementation costs in dynamic and institutional settings grounded in empiricism, with multiple consequences for policy formation.

The long-term use of discounting is highly problematic. For financial decisions spanning a few years or decades, it is an indispensable tool for inter-temporal comparisons, appropriately weighing commensurable costs and benefits that are experienced by the same individual. If extended to cover the longer term and multi-dimensional future costs and benefits of any climate policy action, discount rates have an important influence on decision-making. They simplify calculations and theories, follow the logic of financial markets, and prevent arbitrage and paradoxes of preference reversal (Scrieciu, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis, 2013). There are, however, some that disagree and support the use of a near zero discount rate. The arguments here are twofold. Firstly, there is an ethical or philosophical argument advocating for a zero utility discount rate, on the grounds that the welfare of all generations is of equal importance (Stern, 2007). Secondly, there are many market related interest rates, but for climate mitigation investments it is more appropriate to apply an insurance type interest rate. This is because climate mitigation efforts are better understood as social insurance against disaster, rather than ordinary profit seeking investments. Whenever possible, outcomes that cannot be adequately expressed in monetary terms should not be discounted (Scrieciu, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis, 2013). Nevertheless, since the practice of discounting is widely accepted, and sometimes even expected in climate analyses, choices must be made about the appropriate rates to use, at least for future quantities that lend themselves to monetary valuation. Declining discount rates are, however, starting to appear in climate policy analyses (Lowe, 2008).

8.7 Avoid the monetisation of non-market related elements

Akin to the use of discount rates, monetisation of the environment, health and other social issues has become common practice, but it reduces transparency of the results, and raises a range of ethical and analytical dilemmas (Scrieciu, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis, 2013). Is it necessary to monetise every significant benefit? Are standard values available for non-market benefits?

Three approaches can be used to incorporate both marketed and non-marketed impacts in climate policy analysis, according to Scrieciu et al. (2013). The first entails applying the best available estimates of monetary valuations of all health and environmental impacts. This has the advantage of internal consistency, and creates a bottom-line numerical estimate for any scenario. This is traditional in the economics literature and is required for cost-benefit analysis. The second consists of applying only the most established, least controversial valuations of non-market benefits such as the externality prices for common air pollutants used in energy sector analyses. In addition, all major health and environmental impacts could be reported in their natural units (e.g. health impacts could be reported both in disability adjusted life years (DALYs) and in specific health outcomes). Finally, a third option would avoid all use of monetary valuations of non-market benefits. This would result in all market costs and benefits being reported in monetary terms, while health and environmental impacts are expressed in natural units. For health outcomes, DALYs, as well as surrogate prices, would be avoided. This has the advantage of avoiding the ethical and logical paradoxes of pricing the priceless values of life, health, and nature - at the cost of losing comparability with other studies (Scrieciu, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis, 2013). Both the second and third options are preferable to the first alternative. In a multi-criteria analytic framework, it makes more sense to work with raw measures of health effects rather
than with generalised measures of health, as value judgements can be introduced directly by stakeholders using a multi-criteria decision analysis (MCDA) approach (Chalabi & Covats, 2011).

8.8 Model performance evaluation and verification tools

Gowdy and Salman (2008) indicated that dealing with the problems raised so far, will require innovative approaches, based on sound economic analysis and detailed knowledge of the specific environmental and social conditions at work. There is a need for the development of mechanisms that permit a more equitable and transparent distribution of costs and benefits (Stringer, et al., 2014). Models serve the purpose of creating an evidence base for policies, but they should ideally double as proof of success of said policies and interventions.

Governments and donors are both currently investing in climate compatible development (CCD) with little evidence of triple-wins being delivered in practice, despite sufficient time having passed to adequately monitor and evaluate the utility of the CCD concept in moving countries towards a more climate friendly trajectory and to assess the distributional impacts of CCD in terms of resource allocation and equity across scales (Stringer, et al., 2014). The quantitative assessment of co-benefits is not a straightforward task. Many of the co-benefits are hard to quantify in precise terms, even more difficult if a measurable, reportable and verifiable (MRV) method is required (Puppim de Oliveira, 2013). Model transparency and credibility is, thus, very important and it would be ideal to be able to use the models for assessment and attribution purposes.

8.9 Dealing with risk and uncertainty

According to Weitzman (2007), in the case of climate change, there is pure uncertainty in terms of the potential risks, the prospects for future economic growth, and the proper social discount rate to use. Projections of future climate change are, generally, based on global scenarios of future emissions of greenhouse gases. These emissions scenarios are subject to great uncertainty, as they reflect patterns of economic development, population growth, consumption and other factors that are not easy to predict over a 100-year period (Klein, Schipper, & S, 2005). A large number of emissions scenarios are typically used to account for this high degree of uncertainty.

Economies are highly complex non-linear systems and it is impossible to accurately predict their future evolution (Scricciu, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis, 2013). Having said this, although future behaviour of economic systems cannot be accurately predicted, it is possible to be aware of a range of future states (Hayward & Preston, 1999). Economic analysis incorporating climate change would need to cover the entire spectrum of uncertainty, ranging from unknown uncertainty (e.g. variations around expected system behaviour that cannot be quantified), to uncertainties that can be quantified, be they internal (e.g. relating to modelling assumptions and concepts used) or external (e.g. relating to the unpredictable variation in the phenomena under study).

The latter are beyond the controlling capacity of the analyst, though they can be quantified, sometimes being referred to in the literature as aleatoric or chance events (Daneshkhah, 2004). In practice this might mean that for climate-related uncertainties, analyses and calculations could be performed for at least two distinct scenarios: one representing most likely outcomes, and one representing credible worst-case risks. For macro level socio-economic uncertainties, which may be better understood than climate change, a fully-fledged uncertainty analysis, examining multiple possible values or pathways could in principle be undertaken. However, climate and socio-economic uncertainties are not necessarily separable in all possible futures (Scricciu, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis, 2013). In other words, climate policy-making could draw more on scenario analysis (as is practiced in
climate science) and robust strategies, and choose options that are most insensitive to future climate and socio-economic conditions. Traditional optimisation algorithms based on well-posed objectives and known climate conditions are difficult to apply under uncertainty, and new methods supporting policy-making, favouring robustness and including uncertainty information need to be put forward (Scrieciu, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis, 2013).

The traditional economics approach to such uncertainties converts them to expected values by assuming a probability distribution, which is used to construct a weighted average of likely outcomes (Scrieciu, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis, 2013). This approach, however, is not helpful in the face of catastrophic risks and deeply uncertain probabilities of worst-case scenarios (i.e. events that have very low probabilities of occurrence and very high impacts). Under such conditions, the appropriate probability distribution may be so fat-tailed, that the value of an incremental reduction in emissions could be, technically speaking, infinitely large (Weitzman M., 2009). Weitzman (2007), in a commentary on the Stern Review, writes: "But in lumping together objective and subjective uncertainties and thereby obscuring their distinction... I think that contemporary macroeconomics goes too far and leads to a mind-set that too easily identifies probability (and "economic science") with an exercise in calibration to sample frequencies from past data." Although he does not use the term, Weitzman calls for applying the precautionary principle, to avoid the potentially catastrophic effects of global climate change ( Gowdy & Salmon, 2008).

An alternative economic paradigm, used for low-probability catastrophic risks in other arenas, arises in insurance (Scrieciu, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis, 2013). People buy insurance to guard against things that do not usually happen, but would cause unaffordable losses if they did occur. Insurance policies are, thus, driven by risk aversion, and always fail a simple cost-benefit test (i.e. an insurance company must charge its policy holders more than the present value of the payments it will make to them; to do otherwise would bankrupt the company). Public policy to guard against catastrophic climate risk could be viewed analogously: it insures society against the possibility of extreme losses, since we cannot be sufficiently sure that those losses will not happen. The analogy is not perfect: private insurance covers recurring individual risks with empirically known probability distributions and not fundamentally uncertain threats to human society as a whole. In the face of such threats, we can at best provide a form of collective self-insurance through precautionary policies. This suggests setting safe minimum standards, then seeking a least-cost strategy for achieving those standards (Scrieciu, Barker, & Ackerman, Pushing the boundaries of climate economics: critical issues to consider in climate policy analysis, 2013).

8.10 Summary of development-first modelling requirements

Though there is no single, definitive, commonly accepted definition of development, it is certain that any definition should capture the multi-faceted nature of the concept. In modelling terms, this translates to the need for representing development through multiple criteria as opposed to a singular criterion. Furthermore, any generic model should be able to handle different specific definitions of development as specified by the actual stakeholders involved. Hard coding a particular definition of development will be restrictive and limiting in terms of generic application. Scrieciu et al (2014) suggest modelling approaches that: incorporates systems thinking, complexity, evolutionary and Post Keynesian theory with an emphasis on institutions, non-linear dynamics, and deep uncertainty. In other words, they suggest an analysis that marks a departure from the standard practice in contemporary economics of combining optimisation, equilibrium, and the aggregation of heterogeneous actors, as per the representative agent assumption. With application to climate change, such an approach would explicitly account for systemic effects, risk and uncertainty, technological change, multidimensional
impacts across space and time, ethical perspectives of multiple stakeholders, and the institutional constraints and drivers for climate policy implementation (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014).

It is postulated that meaningful, effective and comprehensive assessment and planning of climate policies should rest on three main principles (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014). The first is that climate change policy has multidimensional implications for human societies and the environment, affecting multiple interests and calling for the consideration of a wide range of values and priorities, which often do not lend themselves to monetisation and aggregation. It needs to recognise the importance of catastrophic risks and irreducible uncertainty, warranting a precautionary approach to climate policy. A solid understanding of the economics of climate change policies would call upon increased empiricism in understanding socioeconomic behaviour and relations, incorporate policy-induced technological change, and explicitly address the role of institutional drivers and barriers to policy planning, implementation, monitoring and verification. The second principle asserts that policy responses to climate change may contribute, if adequately formulated, towards meeting country-specific development objectives, and that there may not necessarily be trade-offs between climate action and the economic performance or poverty alleviation targets of a given country. The third principle states that non-monetary values, uncertainty and the long-term dynamics of environmental, socioeconomic, and technological systems should be inherent to the formulation of any responses to the climate change problem.

A set of good practice evaluation standards (with an emphasis on the socio-economic dimension) that could guide future assessments in the area of climate policy analysis and planning is presented in Table 3. Any meaningful evaluation and effective implementation of climate policy options would need to account for the multiple values, interests, trade-offs and synergies between climate policy goals including their likely consequences, and the development objectives of the country wishing to put into practice its climate policy plans. Moreover, due to the complexity and multidimensionality of the climate change problem, decision-making in this area would have to involve a range of relevant stakeholders (Scrieciu, Belton, Chalabi, Mechler, & Puig, 2014). Identifying and discussing pro-development climate policy options grounded in space and time and which have the potential of being robust across a range of plausible future outcomes, may deliver better suited responses, rather than searching for unique optimal or first-best solutions.

There are many aspects to consider and “no silver bullet” approach to designing a development-first decision support tool. However, from the literature presented, a wish list of model properties that should be incorporated in the ideal decision support tool is compiled and presented in Table 4. Further to this, the standard modelling approaches that should explicitly be avoided when developing such a decision support tool, are listed in Table 5.

In Table 6, cross referencing is done to determine which of the standard and well known operations research tools and techniques can facilitate each of the modelling requirements set out in Table 4. From this analysis, it appears that simulation modelling presently ticks the most boxes. The primary reason for this is that the tool is versatile and can easily be combined with some of the other tools listed to incorporate their strengths into the final product. Simulation provides a relatively transparent way of modelling all the relationships and feedback loops between all the complex and integrated elements of the economy, society and the environment. Systems dynamics modelling is a special type of simulation model, where interactions between model elements are captured and explicitly accounted for. Agent based simulation can be used to model actor’s individuality and preferences, to simulate context in terms of decision making and also to facilitate the inclusion of a-typical, non-rational decisions of actors in the model.
Optimisation modelling is a tool, unlike simulation models, that can provide solutions that the modeller does not dictate. It is useful to extract such solutions when complexity is high, and modellers find it difficult to know whether they have, in fact, considered all the relevant attributes of the system. Optimisation models combined with simulation can lead to models that record incremental changes and progressively build towards the final, globally optimal solution. Another advantage of optimisation modelling is that, without intense computational requirements, a Pareto front of solutions can be generated, facilitating interrogation of the solution space of the problem, as well as trade-offs between elements in the model.

Table 3 Good practice evaluation standards for the socio-economic analysis of climate action

<table>
<thead>
<tr>
<th>Critical issue to consider for climate policy evaluation</th>
<th>General suggestions on good practice evaluation standards for the socioeconomic analysis of climate action</th>
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</thead>
<tbody>
<tr>
<td>Baseline formulation</td>
<td>Consider issues of transparency (such as stating definitions and purpose of the baseline, or providing information on emission factors and technology learning rates used for example) as well as uncertainty considerations (notably the methods used to calculate GDP projections and whether or not sensitivity analyses have been carried out).</td>
</tr>
<tr>
<td>Macroeconomic assumptions</td>
<td>Incorporate and, where possible, endogenously account for assumptions on anticipated growth rates or changes in population numbers, GDP, investment, trade, income and demographic distribution, health status, sectoral employment, government budgets and policies, energy prices, and competing technologies. Climate variability, GHG emissions and climate impacts need to be explicitly included in baselines.</td>
</tr>
<tr>
<td>Technological innovation</td>
<td>Account for policy-induced and endogenous technological change (e.g. as in ‘learning curve’ or ‘learning by doing’ analyses) and include at least a small number of crucial feedback and system dynamic effects of policy choices.</td>
</tr>
<tr>
<td>No- and low-regrets options and co-benefits</td>
<td>Use the best available, disaggregated information on no- or low-regrets options and co-benefits. These will normally be the first priorities in any climate policy proposal, as they reduce the overall costs of a comprehensive climate-policy.</td>
</tr>
<tr>
<td>Monetary valuation and non-marketed impacts</td>
<td>Consider interactions between the economy, environment and society in their multi-dimensional, often non-monetized integrity. Apply only the most established and least controversial valuations of non-market benefits, and in addition, report these in their natural units (including qualitative appraisals).</td>
</tr>
<tr>
<td>Discounting future costs and impacts</td>
<td>Explicitly state the value judgements underlying the (economic) analyses, particularly judgements about the importance of current versus future generations, with implications for discounting.</td>
</tr>
<tr>
<td>Risk and uncertainty</td>
<td>Cover the entire spectrum of uncertainty, including catastrophic risks and irreducible uncertainty, for example, by the development and use of scenario analysis and the consideration of adaptability.</td>
</tr>
<tr>
<td>Institutional constraints and enablers</td>
<td>Identify context-specific institutional factors that might constrain or support climate policy implementation. Account for the market and non-market barriers, or the transaction and transition costs of policy implementation, as well as the contribution of the civic sector and social collective action.</td>
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<tr>
<td>Fiscal sustainability</td>
<td>Explicitly account for climate policy impacts on fiscal sustainability and the short to long run implications for fiscal systems.</td>
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</tbody>
</table>

(Scriciu, Belton, Chalabi, Mechler, & Puig, 2014)
Multi-criteria decision analysis (MCDA), in turn, is a well-suited tool to combine with stakeholder workshops, where stakeholders debate and reach consensus on context specific development goals and priorities. To facilitate such discussion, and drawing inference from it, fuzzy logic can be utilised to eliminate confusion due to linguistic issues. MCDA is also a tool that is designed to cope with the combination of quantitative and qualitative elements and to perform an assessment over multiple criteria, in one model. The use of measuring units in their raw format is preferred, so as not to limit attribution capabilities. In this context, decision analysis under uncertainty speaks to the subset of modelling tools specifically developed to aid in the formulation of robust decisions; robust in terms of both external and internal model parameters.

As there is no single tool that can unilaterally account for all the key requirements listed, it can be concluded that a combination of standard operations research approaches is preferred.

### Table 4 Wish list of the properties of development-first, climate mitigation models

<table>
<thead>
<tr>
<th>Desirable pro-development model properties</th>
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<tbody>
<tr>
<td>A proper representation of utility across the various spheres of society is needed</td>
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<tr>
<td>Accommodate sub-optimal behaviour and decision making</td>
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<tr>
<td>Aim to develop proposals that are not very sensitive to the discount rate used</td>
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<tr>
<td>Complex, adaptive systems modelling approach</td>
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<tr>
<td>Consider the distribution of impacts, not just the average impacts</td>
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<tr>
<td>Enable further understanding of trade-offs</td>
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<td>Entertain multiple objectives</td>
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<td>Focus on achieving global, rather than local, optima</td>
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<td>In the systems context, explicitly identify and consider vicious and virtuous cycles</td>
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<tr>
<td>Model as a non-linear system</td>
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<td>Model change as an iterative process of small incremental changes</td>
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<td>Model should incorporate context specific development goals and priorities</td>
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<td>Must be able to evaluate equity of benefits and dis-benefits</td>
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<td>Participative modelling process and decision making to allow subjectivity</td>
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<td>Proposed actions should ideally be measurable, repeatable and verifiable</td>
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<tr>
<td>Tend towards the precautionary principle and err on the side of caution when losses are expected</td>
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<tr>
<td>Treat development as a system property, instead of summing over elements in the system</td>
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<tr>
<td>Try to envision catastrophic events as well as statistically likely events</td>
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<tr>
<td>Uncertainty needs to be identified and explicitly addressed, to result in robust proposals</td>
</tr>
<tr>
<td>With regards to timeframes, impacts need to be considered on a continuum</td>
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<tr>
<td>Work with basic (raw) units of measurement, as opposed to generalised units</td>
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</tbody>
</table>
## Model approaches to be avoided

- Avoid regression bias entrenched in historic trends
- Avoid using discount rates
- Do not assume general equilibrium
- Do not assume optimising behaviour
- Do not assume rational actors
- Do not assume system or market efficiency
- Do not monetise non-monetary items
- Do not use a technique that is too difficult to understand or to achieve (in terms of data needs, etc.)