# Chapter 9 A Future of Surprises

*Surprise is always relative, which explains why, whenever something unexpected befalls us, there is always someone who 'saw it coming'.*

*- Michael Thompson*

Marco A. Janssen

## Introduction

Integrated models describe the interactions between people, economies and nature to explore possible futures. In this chapter we concentrate on human behavior. Human behavior has too many important dimensions to include them all in a satisfying manner in these models. Simplification is necessary to make progress. The focus of this chapter is on one element, namely the subjective perceptions of reality. The aim of this chapter is to discuss some recent developments in integrating subjective perceptions of reality within ecological-economic models, and to use these models to explore the possibilities and consequences of changing perspectives on sustainable futures.

The variety of expectation about the future can nicely be illustrated by the behavior of a financial market, the place where expectations of companies' futures are valued. According to the "efficient market hypothesis" in economics, price fluctuations are an immediate and unbiased reflection of incoming news about future earning prospects. However, financial markets have experienced large price fluctuations that are not directly related to external disturbances, but are caused by internal dynamics. Behavioral economists argue that psychological factors often lead to more quasi-rational decisions (Thaler, 1992). Multi-actor models are used to study the financial-market behavior, where actors have different strategies in determining expected prices (Lux and Marchesi, 1999). These multi-actor models have been found useful to explain observed fluctuations on financial markets.

In this chapter we deal with expectations on sustainable development of ecological economic systems. Sustainable development is a rather vague concept related to maintaining opportunities to meet the needs of future generations. Because it is not clear what these needs are, and how they might be satisfied, various interpretations exists on the implications of the desire for sustainable development on environmental policy. Should this policy be preventive, adaptive or reactive? The different perceptions of reality will lead to surprises when expectations significantly differ from observations. As suggested by the adaptive cycle (Holling et al., chapter 2) these surprises can trigger changes in perception of reality and related resource management.

Controversies and different interpretations have a long history in determining how to manage the environment. For instance, Malthus (1789) regarded food production as a land-limited resource that could not possibly be increased quickly enough to keep in pace with a growing population. His expectation did not come true for various reasons, among them the sharp increase in agricultural productivity and the decrease in birth rates. Another example is provided by the Limits to Growth report to the Club of Rome (Meadows et al., 1972), which concluded from a model-based analysis that the continuation of depletion of resources would result in a collapse of the world economy. However, the oil crisis of the 1970s led to intensification of exploration efforts that located additional reserves, and induced investments in energy efficiency and renewable energy sources (Meadows et al., 1991). The simulations made in 1971 did not include either the oil crisis or possible responses to it. The complexity of the system is seriously underestimated in such analyses. This is particularly true with respect to the response and adaptation options and the capability of humans to apply and expand such options.

In this chapter the inclusion of perceptions of reality and surprises within integrated models are explored. First, the field of integrated modeling is discussed in the context of the theories on scale and resilience as applied in this book. Then theories of different perceptions of reality are explored, especially the Cultural Theory. This theory is then used to construct an approach to explore institutional change, which is finally applied on an integrated model of global climate change.

## Integrated Modeling

In this chapter we use simple models to study the behavior of the system during the adaptive cycle, as was done in other chapters in this volume (Carpenter et al., chapter 6; Brock et al., chapter 7; Scheffer et al., chapter 8). More specific, so-called integrated models are used to study the interactions between human activities and ecosystems. Such models link simplified versions of expert models into an integrated framework (Janssen, 1998). Integrated models can be used for a variety of reasons. Understanding is one reason, management is another. Ideally, one should integrate insights from various disciplines such as economics, psychology, ecology and physics. The integration should be clear and acceptable to leading scholars in various disciplines. The purpose of such models is to study key interactions between the various elements in a qualitative way, and find ways to improve the future quality of the system, however it is defined.

### Modeling Human Behavior

Of all elements in integrated models, behavior of human beings is probably the most complex. Since theory in social science is rather fragmented, models of human behavior that are useful for simulation models are not generally agreed upon. Integration of human behavior into integrated models is therefore biased at the start, through the elements of social science that are assumed to be important for our purposes and that can be included into a formal model. Although formal models cannot include every nuance of our understanding, they pose clear assumptions and the resulting consequences.

Traditionally, economics has been the social science that developed formal models of human behavior. Conventional economics theory represents people as collections of rational actors, the *Homo Economicus*, to study human behavior. The rational actors are self-regarding individuals maximizing their own well being. However, the powerful concept of the rational actor has not been validated by experimental research in economics and psychology and is therefore an oversimplified model of human behavior (Gintis, 1998; Loomes, 1998; Ormerod, 1994; Thaler, 1992).

Since the early 1950's social scientists have used computers to simulate behavioral and social processes. Economist Herbert Simon pioneered in developing models of bounded rationality (Simon, 1957; 1996). Furthermore, due to the development of new simulation techniques, like cellular automata, genetic algorithms and neural networks, and the widespread availability of personal computers, social scientists explore new ways of modeling human behavior (Vallacher and Nowak, 1994; Gilbert and Doran, 1994; Gilbert and Conte, 1995; Conte et al., 1997; Liebrand et al., 1998 and Jager, 2000). These simulation models use interacting agents to study social processes in simple and complex environments.

**A General Framework**

Like ecological processes, we can describe the various components of integrated models in line with the adaptive cycle. In this chapter a general framework of systems will be used that is based on the many case studies described in this book and other literature (e.g. Berkes and Folke, 1998; Diamond, 1997; Giovanni and Baranzini, 1997; Gunderson et al., 1995b). The so-called *complex ecological-economic systems* refer to the transdisciplinary approach of ecological economics and to the study of complex systems (Anderson et al., 1988; Costanza, 1991; Holland, 1995; Waldrop, 1992). Four basic elements dominate the descriptions of the case studies: economic agents, institutions, physical economic systems and ecosystems. Studying complex ecological-economic systems requires a transdisciplinary approach to study these four subsystems and their interactions.

Each subsystem can be described in line with the adaptive cycle. They can all be described as a dynamic process where change is triggered by surprises. Surprises can be internal or external. Internal surprises evolve from the subsystem itself. External surprises are caused by another subsystem or natural surprises like earthquakes and floods. Since each subsystem influence other subsystems, an internal surprise in one subsystem can lead to surprises and changes in the other subsystems. For example, the pig plague in the Netherlands during the 1990's was started at farms in Germany where boars and pigs lived together. Illness among the boars led to a pig plague in Europe. Because of the high density of the Dutch pig industry, stimulated by government subsidies, the consequences were severe for the Netherlands. The financial costs reached billion dollars. There was a need to reduce acid-rain-causing emissions from pig industry. The pig plague provided the government the opportunity to change the pig industry in the Netherlands.

In the case of global climate change various stakeholders have different interests in using or producing energy. The physical economic system consists of capital and energy production. Institutions can change the rate of change of the capital stock, and the degree of reliance upon alternative energy resources. Stakeholders can become surprised when the changes of ecosystems are in a different speed than expected. This can trigger the collapse of current institutions and the initiation of new types of institutions.

The four components of complex ecological-economic systems can be described as follows (Table 9.1):

- Economic agents are the total of consumers and producers in an economic system. Decisions made by these agents, the households, the companies, are made by people. The decisions are based on the satisfaction of needs, which vary from subsistence (physical and mental health of persons, profits of a company) to identity (big car, market leader). How to satisfy these needs is based on the abilities and the opportunities of the agents.
- Institutions can be defined as a set of rules used by a group of individuals to organize repetitive actions that affect this group and can affect others. Institutions are made up of formal and informal constraints. Formal constraints are rules, laws and constitutions. Informal constraints are norms of behavior. Institutions often react to surprises by adding additional rules to repair

external effects. Adding new rules can occur in a relative brief time, but changing or removing rules is usually a slow process.

- The physical economy can be described in stocks and flows of energy and materials. In fact, the physical economy can be considered to be the metabolism of the economic system. The stocks and flows are designed with a functional purpose: houses to live in, infrastructure for transport, electric equipment to make housekeeping more comfortable, etc. Materials and energy often disperse in the economic and environmental system in low concentrations. The flows of materials and energy use can relatively changing rapidly compared with the slow changes in the accumulation of materials in various stocks in the economy and the environment.
- Ecosystems are the collections of living and non-living components of the environment functioning together. The human population and human-made environment were described in more detail above in the three other components of complex ecological-economic systems. Ecosystems also involve physical, chemical and biotic constituents of remarkable complexity. Some constituents of ecosystems change rapidly (e.g. certain chemical reactions or interactions among organisms) while others change slowly (e.g. geomorphological changes or soil weathering). Evolutionary changes in the biota can adapt to changes in the environment and account for much of the resilience of ecosystems. But the rate and capabilities of evolutionary change have limits. Human disturbance can produce irreversible changes in ecosystems, such as biodiversity losses, as well as changes from which recovery is slow, such as deforestation. These are the changes that forward-looking institutions must anticipate to avoid severe social costs.

Table 9.1: The characteric elements of complex ecological-economic systems.

| | Economic agents | Institutions | Physical economy | Ecosystems |
|---|---|---|---|---|
| Components | consumers and producers: households and companies | Formal and informal constraints | Material and energy stocks and flows | Populations and non-living environment |
| Diversity | Needs, opportunities, abilities | Rules, laws, norms & traditions | Functional | Genetic, functional (biodiversity) |
| Surprises | Bankruptcy, disease, | External effects | Technical or physical collapse | Fire, floods |
| Fast variables | Individual decisions | Adding new rules | Material and energy flows | Behavioral change |
| Slow variables | habits | Changing or deleting rules | Material stocks | Evolutionary change |

Although there are many different possible surprises who can trigger structural changes in the system, we will concentrate on the different possible perceptions of reality, which can lead to surprises when the system is behaving in different ways than expected. In the next paragraph we will describe classifications and dynamics of perceptions of reality.

## Perspectives on Reality

Thompson et al. (1990), in their Cultural Theory, give a general description of perspectives on natural and human systems and social relations. This theory will be used in this chapter to illustrate the possibilities of modeling (changing) perspectives. The motivation to use the Cultural Theory, and not another classification, is based on the inclusion of perspectives on human as well as natural systems, the claimed generality, and the determinism of explaining perspectives' rationalities which makes it suitable for modeling purposes. This does not mean that the modeling approach described in this chapter cannot be applied using other classifications of human behavior (Janssen, 1998). The large number of theories in social science force us to make a choice for one theory without abandoning the others.

Thompson et al. (1990) borrowed anthropological insights from Douglas (1982) and combined these with ecological insights elaborated by Holling (1973, 1986). Thompson et al. (1990) claim that notions of human and physical nature are socially constructed, and that the four myths of nature derived from ecologists closely coincide with certain ideas of nature. These myths of nature are in line with caricatures of nature flat, balanced and anarchic as described by Holling et al. (chapter 1). The crux of their theory is that societies can be characterized along two axes, labeled "group" and "grid" (Figure 9.1). Douglas and Wildavsky (1982) proposed the grid-group typology to characterize societies along two axes. The group axis reflects the extent to which an individual is incorporated into bounded units. The greater the degree of incorporation, the greater the subordination of the individual choice to the group determination. The "grid" axis denotes the degree to which an individual's life is circumscribed by externally imposed prescriptions. The more binding and extensive the range of prescriptions, the less scope there is for individual negotiations. It is the social control that sets the perspectives apart from each other. The group-grid characterization yields four different perspectives (or worldviews). They inform the individual's perception of the world and his/her behavior in it, and are labeled in turn as: the hierarchist, the individualist, the egalitarian, and the fatalist.

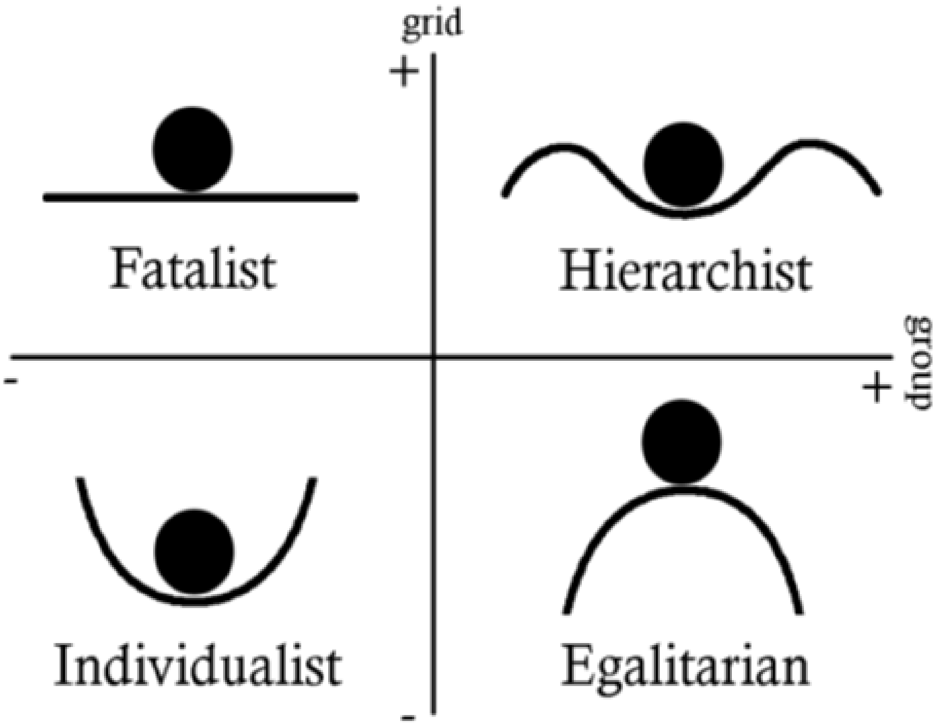


Figure 9.1: Cultural perspectives (Source: Schwartz and Thompson, 1990)

Three of these perspectives, or paradigms, are active. Holders of these perspectives think they can structure the world. The hierarchist lays down the rules. The individualist is the pioneering innovator. The egalitarian criticizes both the rules established by the hierarchist and the exploitative attitude of the individualist. The fourth category, the fatalist, is passive. The fatalist is a necessary loser in the world of the individualist, and fatalists occupy the lower echelons in the hierarchy of the world as envisaged by the hierarchist. For the egalitarian, the existence of fatalists is evidence of the injustice and irresponsibility of the other two active perspectives.

Each individual represents a mixture of perspectives, and the mix changes over time. Thus the adoption of perspectives by actors is a dynamic process. Change occurs because of 'surprise', that is the discrepancy between expected and the actual, which is of central importance in dislodging individuals from a previously adopted perspective. Adherents to each of the four perspectives are, as it were, in competition for new adherents to their particular perspective, but are dependent on one another at the same time. In other words, all of the perspectives are needed to ensure each one's viability (Thompson et al., 1990).

Although some use the Cultural Theory to describe individuals behavior, it has also been used to describe different types of institutions (Rayner, 1991; Thompson and Rayner, 1998; O'Riordan and Jordan, 1999). They (op cit.) only consider three 'active perspectives', that is the individualist, the hierarchist, and the egalitarian that correspond to different types of institutions: market, hierarchy and community, respectively (Rayner, 1991; Table 9.2).

Table 9.2: Characteristics of cultural perspectives

| | **Individualist** | **Hierarchist** | **Egalitarian** |
|---|---|---|---|
| **world view** | | | |
| idea of nature | skill-controlled cornucopia | isomorphic nature | accountable |
| myth of nature | natural benign | nature perverse/tolerant | nature ephemeral |
| concept of human nature | self-seeking | sinful | born good, malleable |
| **Management style** | | | |
| Institution | market | hierarchy | community |
| driving force | growth | stability | equity and equality |
| type of management | adaptive | control | preventive |
| attitude to nature | laissez-faire | regulatory | attentive |
| attitude towards humans | channel rather than change | restrict behavior | change social environment |
| attitude to needs/resources | expand resource base | rational allocation of resources | need-reducing strategy |
| economic growth | preferred: aim to create personal wealth | preferred: aim to avoid social collapse | not preferred |
| risk | risk-seeking | risk-accepting | risk-aversive |

*Individualists and market institutions:*

Market institutions are based on short-term expectation and immediate returns on activities and investments. Market institutions pay little attention to intertemporal responsibility. Future generations are assumed to be adaptive and innovative to response to problems then, just as the present generation copes with current market conditions. Human impacts on ecosystems will be reduced by markets only when environmental damage causes markets to adapt.

*Hierarchists and hierarchy-based institutions:*

According to the hierarchy-based institutions, economic organization and social behavior are legitimated by top-down rule-bound structures that intervene in the dominant social order. The hierarchical regimes contribute to an ordered expectation of the future. Concern for future generations is strong but balanced by the needs of the present generation. Scientific research will help to identify the boundaries within natural systems are stable. Often hierarchical institutions use cost-benefit analysis to help balance the risks.

*Egalitarians and communities:*

Egalitarian groups feel a strong responsibility for the future, but their trust in formal institutions is weak. Communities are based on equity with other actors, nature and future generation. To reduce the risks to future generations and to sustain nature, egalitarians prescribe precautionary measures to reduce disturbances of our fragile natural system. Limiting the pressure on the environment is implemented by voluntary reduce the needs for harmful consumption patterns.

Of course, in the real world, agents and institutions rarely express their views in such a simple way. They are in constant interaction and have strategic and public relations in mind as well. Moreover, positions may be non-identical or even inconsistent when stakeholders and institutions share only part of the underlying values and judgements. Nevertheless, this framework captures the crucial idea that a set of heterogeneous agents can have different worldviews and related management styles (Janssen and de Vries, 1998).

Trisoglio et al. (1994) have characterized perspectives according to two dimensions: (1) how is the world actually works - the functioning of nature; and (2) how should it be acted upon - the management style or institution (Table 9.3). A management style is correct insofar as it is based on a corresponding view on how the world functions. Trisoglio et al. (1994) refer to this situation as utopian: the management style and worldview of agents corresponds with the functioning of nature. If, on the other hand, a management style is inconsistent with the way nature works the situation is dystopian. For example, fisheries assuming that the fish population will recover very fast after each catch will be confronted with a dystopia, when the resource becomes depleted. Next to collapse dystopias, dystopias can also have a positive bias when resources recover faster than expected.

Table 9.3: Different combination of functioning of nature and management styles

| | | Institution | | |
|---|---|---|---|---|
| | | Community | Hierarchy | Market |
| Functioning | unstable | Utopia | Dystopia | Dystopia |
| | stable within limits | Dystopia | Utopia | Dystopia |

| | | | | |
|---|---|---|---|---|
| of Nature | stable | Dystopia | Dystopia | Utopia |

The literature on utopias has a long history (see for example, More, 1516; Kumar, 1987; Proops, 1989; Achterhuis, 1998). Sometimes utopias are viewed as dreamtime scenarios, but Achterhuis (1998) clearly explained that utopias may be dreams of an individual, in practice they will turn out in nightmares because of the rules which force the individuals to behave in an utopian way, in the spirit of “all people are equal but some are more equal” (Orwell, 1946). The Orwell novel refers to the communism regime, implemented in line with an ideology on the how the world should have to function. We now know that the world functions not in line with the assumptions of communism, and the supposed utopian paradise become a dystopian nightmare. Finally, the communistic institutions collapsed, although in some countries like Russia, the system seems to remain in the $\alpha$ phase.

The previously mentioned doomsday scenarios of Malthus and Meadows et al. can be seen as dystopias: human behavior and (lack of) policies are discordant with nature’s resource potential and resilience. Meadows et al. (1972, 1991) have also presented scenarios that avoid catastrophe by combinations of policies - these can be interpreted as utopias. Bossel and Strobel (1978) simulate utopias by inclusion if explicit adaptive behavior.

## Surprises and Institutional Change

The utopia/dystopia approach can be used to explore a variety of images of the worlds’ future (Rotmans and de Vries, 1997). However, this approach is static in the sense that an emerging dystopia does not induce adaptive behavior. If the system collapses, the agents do not respond. Hence, the scenario outcomes are rather implausible, both for utopias as well as dystopias, although they give interesting insights in the role of uncertainties.

The approach discussed here assumes that the agents change their preferred management style if observations about the world are surprising enough, that is, if they differ enough from what they expect on the basis of their world view (Thompson et al., 1990). In line with Gunderson et al. (1995a) the adaptive cycle can be used to describe changes and adaptation of institutions (Figure 9.2).

Agents' management style can be influenced by variations in their myth of nature. Gunderson et al. (1995a) define the adaptive models to describe dynamics of resource management institutions based on a large number of case-studies.

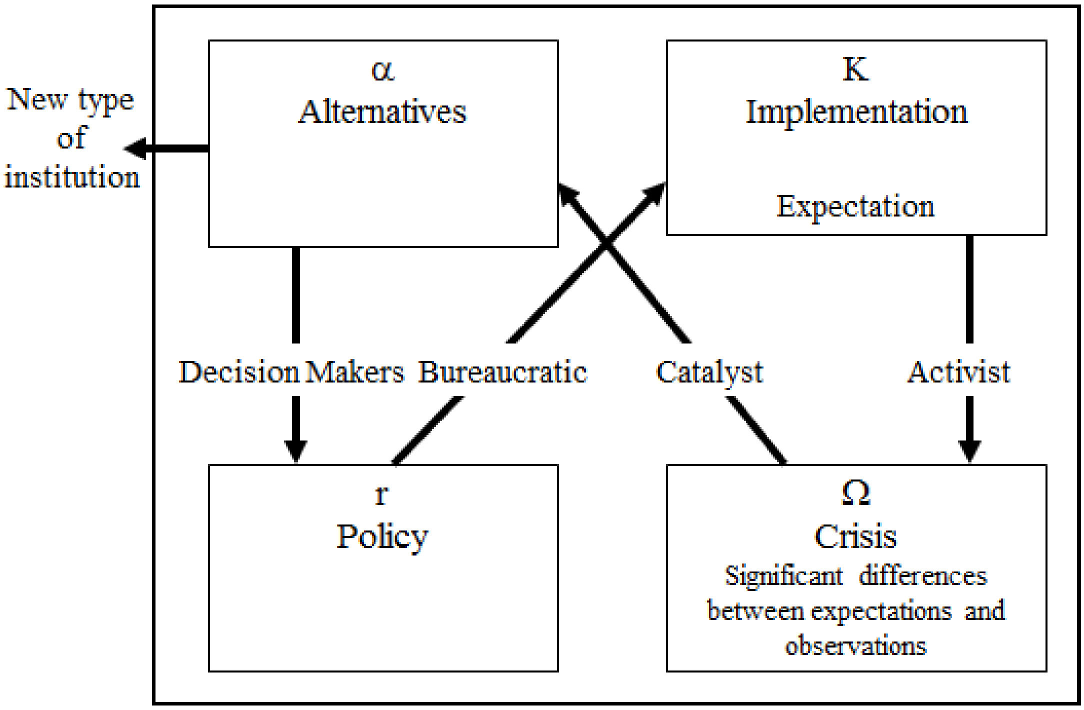


Figure 9.2: Four-phase heuristic for institutions (adapted from Gunderson et al., 1995a).

The *r* phase is defined as the formulation of a policy. If this policy is successful this leads to increasing bureaucratic processes to formalize and institutionalize policies. The expectations of the institutions are mainly based on insights and information during the time policies were formulated. Since policy was considered to be successful no new investigation is done on the quality of the expectations. Those groups with other perspectives on reality, leading to other expectations and preferred policies, will challenge ruling institutions. In the event of a surprise the ruling institution is confronted with evidence that their expectations do not hold anymore, which can result in a crisis. Such surprises can be natural disasters, economic collapses of companies or nations, epidemic diseases, scientific and technological revolutions, and so on. After the start of such a crisis a period will start in which various alternative policies exist how to react to the surprise. This can lead to the continuation of the ruling type of institution with new policy initiatives, or a flip to a new type of institution.

The three types of institutions that are defined in the previous sections leads to a scheme of possible flips between institutions. Each type of institution can be viewed as a stable state in a dynamic process, but can flip to another state when a surprise shakes the existing institutional system.

In the following section an application is described on global climate change. Uncertainty, unclear signals and long time scales are important elements of the climate change problem. Various myths of nature are claimed to hold for the climate system by the important stakeholders. Because of these elements, the global climate change problem is a perfect example to illustrate the modeling of institutional change in line with competing worldviews.

The model used for this application can be downloaded by the reader from the [NCEAS/Website]. The reader can explore the consequences for alternative assumptions in an interactive way.

## Changing Perspectives on Global Climate Change

### Problem Description

During the past two centuries, the atmospheric concentrations of greenhouse gases have increased. The most important greenhouse gas, carbon dioxide, increased steadily from 280 ppmv (around 1800) to 360 ppmv in 1990s. Increases in the atmospheric concentrations of greenhouse gases will increase the global mean surface temperature of the Earth. However, the magnitude, the rate, and the patterns of global climate change that these changes will produce is uncertain, and their impact on the biosphere and humanity is even more uncertain.

Understanding the consequences of climate change is a complex issue, because of our limited understanding of the global system and since observations of the climate system are influenced by various natural factors such as, for example, volcanic activities, fluctuations in solar activity and anthropogenic factors such as variations in albedo due to land use changes, changes in tropospheric and stratospheric ozone concentration, and sulphur emission from industry.

### Perspectives on Climate Change

Given the enormous uncertainties and the important economic consequences of a severe climate change or strong emission reductions for various economic sectors and regions, it is of no surprise that many controversies exists around human induced climate change. Important problems relate to the unequal vulnerability of ecosystems, the unequal responsibility for historical emissions, and the unequal economic and technological perspectives to reduce emissions. For example, the agricultural sectors in Canada and Russia will benefit from a climate change, while countries with large river-deltas like Bangladesh, and the small island states in the Pacific Ocean, will heavily been affected by a sea level rise. Furthermore, measures to reduce $CO_2$ emissions will have negative effects for stakeholders like coal producers in the USA, and oil producers of the OPEC, while other stakeholders, investing in alternative energy supplies will benefit. The institutions as defined in the last section can be characterizes as follows for the energy-climate debate (de Vries and Janssen, 1996; Janssen and de Vries, 1998). The classification of the Cultural Theory will be used as a tool to structure the different types of stakeholders, and will be used to explore alternative scenarios.

*Individualists:*

For the market institution, entrepreneurial freedom and unhampered working of market forces gives the best guarantee of increasing material wealth and at the same time solving resources and environment problems. If energy supply companies can operate in a regime of free trade and with a minimum of government regulation and interference, price signals will steer the transition away from fossil fuels before they are depleted. The key resource is human ingenuity: human skills generate science and technology, which will bring options one cannot even imagine at the present. Concerning the climate change debate, the market institutions' view of a benign natural system leads them to believe that climate change will be mitigated by known and hitherto unknown dampening feedbacks. The market institution emphasizes the opportunities that arise from the search for new resources and new technologies to supply and conserve energy. Policy measures like a carbon tax are viewed as unnecessary and may actually be quite harmful to the legitimate aspiration of the less developed countries to spur economic growth.

*Hierarchists:*
The hierarchist wishes to avoid disruptions to the smooth functioning of the energy system in view of its consequences for economic growth and voter behavior. To this end the hierarchist institutions of society will anticipate and respond on the basis of scientific expert knowledge. There is a preference for a risk-reducing control approach and for reliance on and legitimation by the outcomes of cost minimization and cost-benefit analyses. The hierarchist will make a prudent assessment of the potential for energy conservation and have an institutional bias towards large-scale supply-side options. There will be a cautious approach to the issue of climate change, judging it in terms of 'acceptable risks'. Hierarchists will support cost-effective 'no regrets' measures that reduce the risk of climate change, but they are keenly aware of the fact that fast and stringent cutbacks in $CO_2$ emissions may be socially disruptive and create competitive disadvantages. Hierarchists prefer unambiguous, scientifically robust indicators on which to found their analyses and policies.

*Egalitarians:*
The egalitarian or community-based institution wishes to reduce inequity and stresses the rights of those without a voice: our children, the poor and nature. High and rising $CO_2$ emissions are seen as one more sign that humans are maltreating the earth and that this may lead to catastrophes. Being risk-aversive, community institutions consider all uncertain processes and feedbacks to amplify climate change. They also wish to take account of feedbacks or catastrophic impacts, which are strongly disputed within the scientific community. On the other hand, egalitarians tend to ignore potential negative feedbacks. This leads to a preference for the 'precautionary principle'. Energy futures will be judged not only in terms of costs, but also with regard to distributive aspects and ecological impacts. Hence, policies should be based on assessment studies of the possible impacts from anticipated increases in temperature and sea level. No, or only modest, economic growth is to be preferred. There will be a preference for decentralized and clean technologies, and therefore a natural tendency to focus on energy end-use needs and efficiency. Egalitarian's estimates of fossil fuel resources are on the low side, whereas the prospects of renewable energy sources are usually on the high side, if compared with the hierarchist perspective. Egalitarians believe that development of renewable sources should be strongly supported by government sponsored research and technology programs.

**Utopias/Dystopias of Climate Change oriented Futures**

A simple integrated model of economics and the climate system is developed to explore different perspectives on climate change. This model is based on existing economy-climate models, such as those found in Nordhaus (1994); Manne et al. (1994); Hammitt et al. (1992) and Lempert et al. (1996). Previous versions of the model are described in detail in Janssen (1998) and Janssen and de Vries (1998). The version used here can be found on the NCEAS website.

In the economic part of the model the economic output is simulated as a function of capital and labor inputs, technological progress and climate change induced damage costs. $CO_2$ emissions are related to the fuel mix of supply energy demand, and the energy intensity. The climate system describes the concentration of $CO_2$ as a result from antropogenic emissions using a reduced-form carbon cycle model (Maier-Reimer and Hasselmann, 1987). Then the radiative forcing and the resulting temperature change are calculated.

The economic agents have to decide how much they will invest from the economic output in new capital, and how much they will consume. Furthermore, they have to decide how fast the share of fossil fuels should be reduced. However, in making these important decisions the agent is confronted with large uncertainties on the pace of technological improvements in the economy and of the energy conservation transition. Moreover, large uncertainties exist on the sensitivity of temperature change due to increasing $CO_2$ concentration, the economic cost of reducing $CO_2$ and the economic damage incurred to the economy by a possible climate change.

Given the uncertainties in the integrated economy-climate system different possible functions of nature are defined in model terms, using the myths of nature. Moreover, by assuming a variety of responses from agents with different perspectives we can define the institutions' management styles.

Table 9.4: Assumptions for implementing perspectives in an economy-climate model.

| | **Market** | **Hierarchy** | **Community** |
|---|---|---|---|
| **World view** | | | |
| Technological development | high | Moderate | Low |
| Climate sensitivity | low (0.5 $^{o}$C) | best-guess (2.5 $^{o}$C) | high (5.5 $^{o}$C) |
| Damage costs | none | moderate | high |
| Mitigation costs | high | moderate | low |
| **Management style** | | | |
| Investment | maximizing economic growth | stable long term growth | no expansion of capital stock |
| Climate policy | only policy when damage costs become severe | increase efforts when temperature remains to increase | fast reduction of use of fossil fuels |

The utopia of each perspective is presented assuming that the worldviews of the agents fit with their management style. By implementing the assumptions of Table 9.4 into the integrated model projections are derived for economic output, fossil $CO_2$ emissions and temperature change for each utopia (Figure 9.3). Note that there are already differences in the present temperature change that visualize the different estimates of human induced temperature change over the last 100 years. In the utopia of the individualist, economic growth is greater than 2 per cent per year throughout next century. Because the market institution expects only a modest decline in energy intensity, $CO_2$ emissions soar to over 30 GtC in 2100. In the world view of the individualist, the climate system is also believed to be quite insensitive to human disturbances of the carbon cycle and hence these high emission cause only a small increase in the global temperature of 0.5 $^{o}$C in 100 years. This temperature change has no significant impact on economic activities, so that here is no policy response and the use of fossil fuels is not restricted.

In the hierarchist utopia, the economy grows at a stable rate of 1.5 per cent per year. The $CO_2$ emissions keep increasing and so does temperature change. However, the hierarchist management style responds to the rising temperature by accelerating the phasing out of fossil fuels and the temperature increase can be stabilized at about 1.5 $^{o}$C above present values. This is assumed to be the upper range of what is considered acceptable in many official (governmental) studies.

In the utopia of the egalitarian, economic growth is approximately 1 per cent per year and the $CO_2$ emission from fossil fuel combustion start falling after 2015 because of the policy to accelerate the fossil fuel transition. Due to the sensitivity of the climate system the temperature increases still up to 2.5 $^{o}$ C in the utopia of the egalitarian.

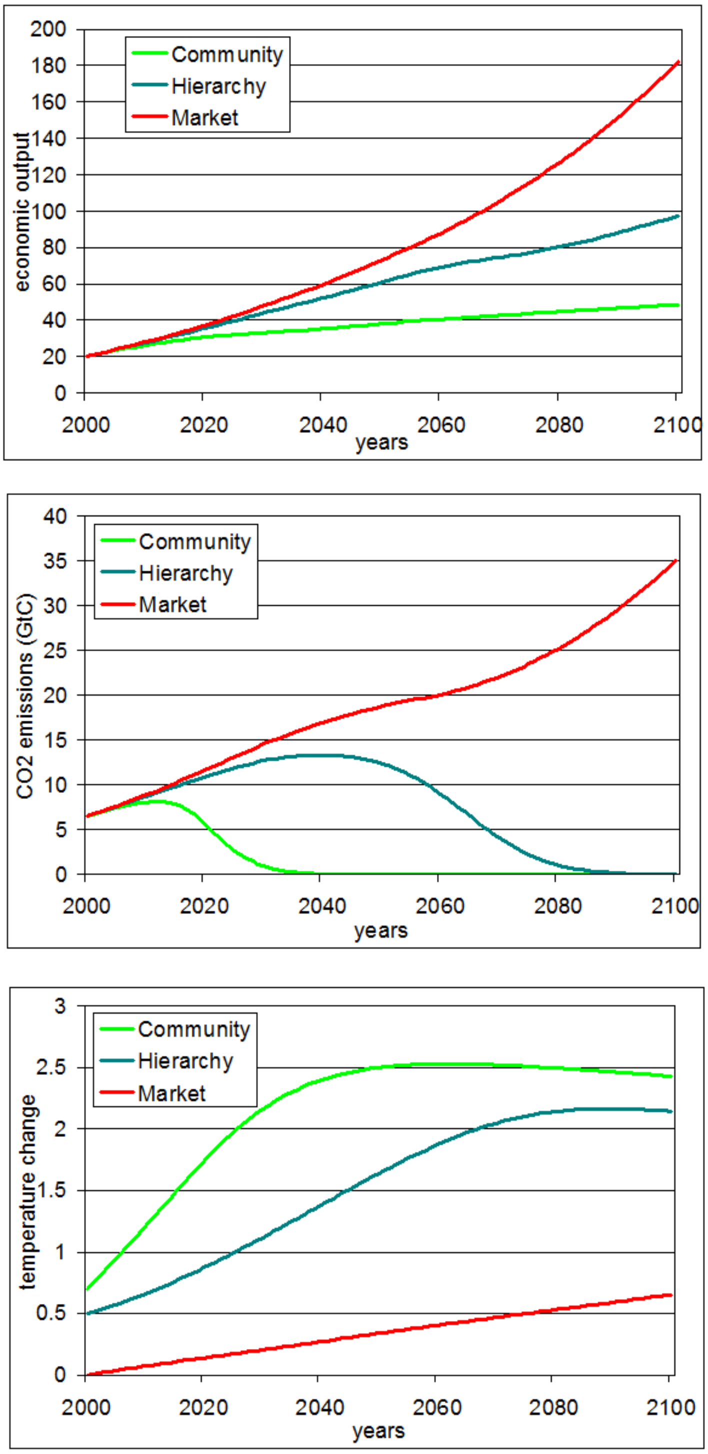


Figure 9.3: Economic output (A), $CO_2$ emissions (B) and temperature change (C) of utopian futures in relation to climatic change according to the three types of institution.

Interesting situations emerge in dystopias-scenarios in which the functioning of nature and the management style are not in agreement. Figure 9.4 presents the most profound dystopia for the same three model variables: the nightmare of the egalitarian. The worldview of the egalitarian is assumed to be correct, that is, the climate system is quite sensitive to increased $CO_2$ concentrations, but economic aspirations and human related feedbacks to temperature rise are based on a management style of the market institution. In this situation, with the integrated system functioning according to the worldview of the egalitarian, a management style of the market institution leads to a collapse in economic development due to high economic growth aspirations together with severe impacts of climate change. The emission reduction measures are implemented too late to avoid a temperature increase in excess of $4^{o}C$. This type of dystopia is the one that has been sketched regularly by environmentalist groups who fear that the prevailing economic growth aspirations will spell environmental catastrophe.

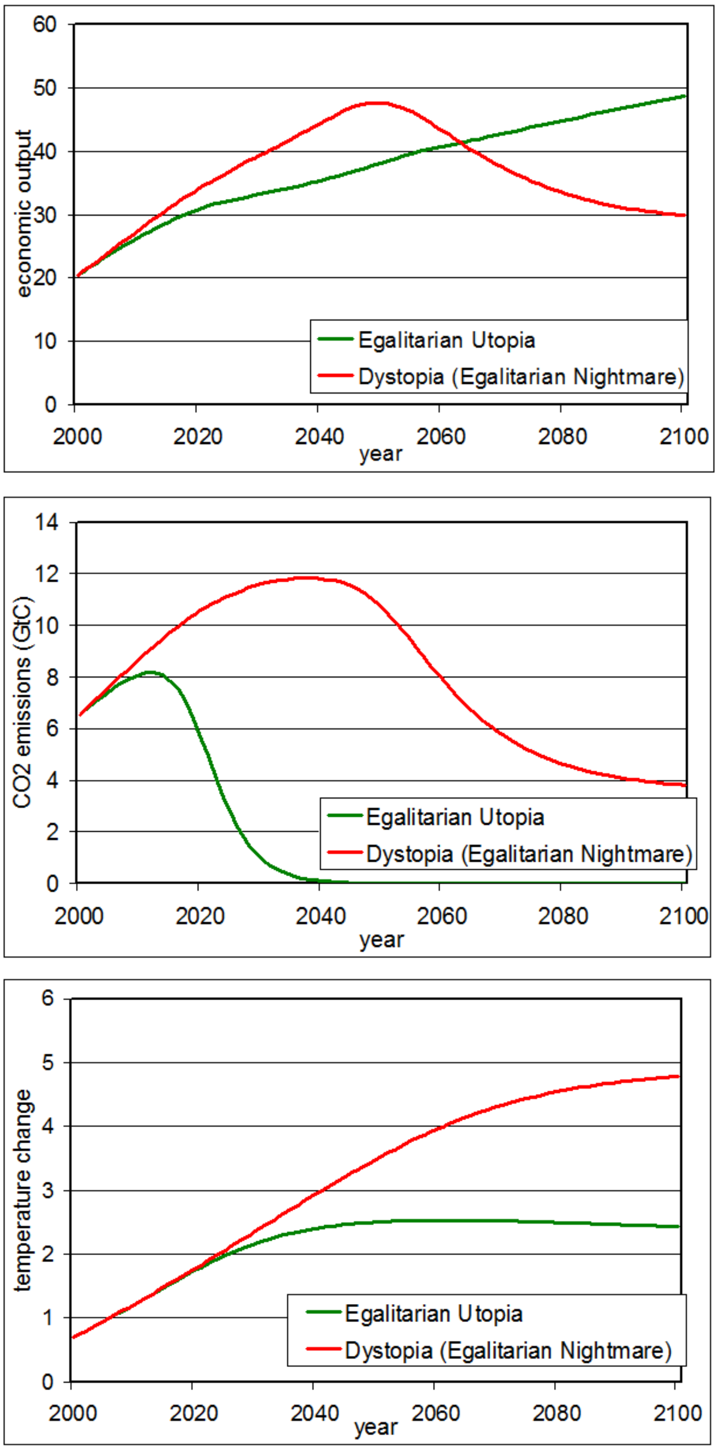


Figure 9.4: Egalitarian utopia compared with an egalitarian nightmare, which is a dystopia for the case that a market institution rules a unstable system, for the indicators economic output (A), $CO_2$ emissions (B) and temperature change (C)

**Changing Perspectives in face of Climate Surprises**

The model experiments in the previous section have an important assumption: that human society does not learn from observations about how the real world actually behaves. In the case of a utopia, since the world fits one's expectations neither learning nor adaptation are needed. However, in the case of a dystopia, there is a mismatch between expectations and observations. In this section agents are assumed to be able to learn and adapt so as to avoid a dystopia instead of rigidly sticking to a fixed policy as disaster unfolds.

According to Thompson et al. (1990), people are assumed to abandon their perspectives in the event of surprise, that is, if observations differ from expectations. People who adhere to a certain worldview will switch to another one if it can better explain the observed behavior of the system. Here, institutions are assumed to follow the adaptive cycle as described in Figure 9.2. This is implemented by a set of simple rules. For each type of institution a fitness function is defined which values the difference in expectations and observations of the indicators temperature change and economic growth. A threshold value of the minimum fitness value for the ruling institution is defined. When the fitness value of the ruling institution drops below the threshold value, a period of crisis starts. The type of institution with the highest fitness value is assumed to be chosen as the new institution. The longer a certain type of institution rules, the bureaucratic forces that maintain the institution typically cause it to increasingly ignore differences between expectations and observations. The increasing ignorance can be modeled by reducing the degree that a mismatch between expectations and observations lowers an institutional fitness. The resulting framework is depicted in Figure 9.5. The circle represents the ecological economic model of the real system. The triangle represents the fitness of the different myths of nature. The point in the triangle represents the average myth of nature of the population of agents. The more a myth of nature fits exclusively to the observations, the more the circle will move to one of the corners. A crisis occurs when the observed myth of nature differs significantly from the related institution. Based on the worldviews of the agents, the institutions remain the same, or flip to another type of institution.

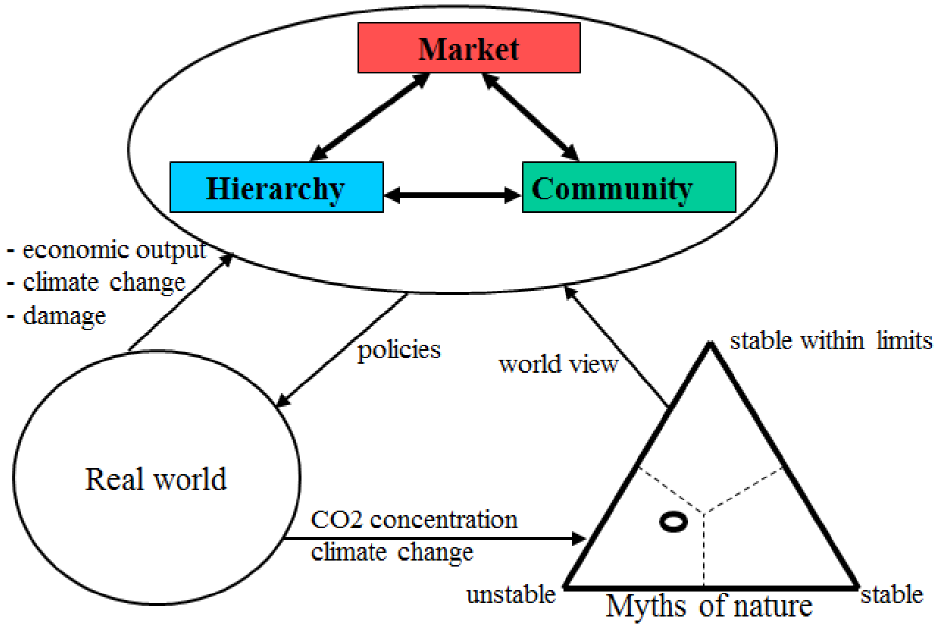


Figure 9.5: Schematic overview of the model: The real system, the institutions, and the myths of nature.

The dystopias depicted in Figure 9.4, may change over time, so that the market institution becomes unfit and gives way to dominance by the community institution. The results shown in Figure 9.6 from modeling exercises with changing institutions. Due to changing management styles the phasing out of fossil fuels is started earlier, which prevents extreme temperatures and high damage costs.

Three types of possible adaptations are implemented. First, the standard one is denoted by *Learning*. The market institution remains in power until 2030 when the observed temperature change differ significantly from expected values, and the damage costs due to climate change begin to increase significantly. The shift to a community institution leads to a phase out of fossil fuels around 2050. Compared with the dystopia, the change of institution leads to a reduction of temperature change of 1 $^{o}$ C. If we introduce ignorance of a modest degree, the adaptation is delayed with 20 years and the temperature change in 2100 is only 0.5 $^{o}$ C lower than the dystopia. When the *Learning* case is confronted with variability in temperature change, surprises occur earlier, because of a higher chance of extreme events. This results in a somewhat earlier change of institution. In sum, adaptation of management style prevents extreme consequences of climate change. Ignorance will slow adaptation, and climate variability can accelerate adaptation.

Learning in a world ruled by uncertainties will not lead to utopian values of the main indicators. Due to the slow dynamics of the carbon cycle and the inertia in the energy system, a build up of atmospheric $CO_2$ cannot be reduced at once. In fact, the range between the utopia and dystopia indicator values represents the space of possible paths in case of learning agents.

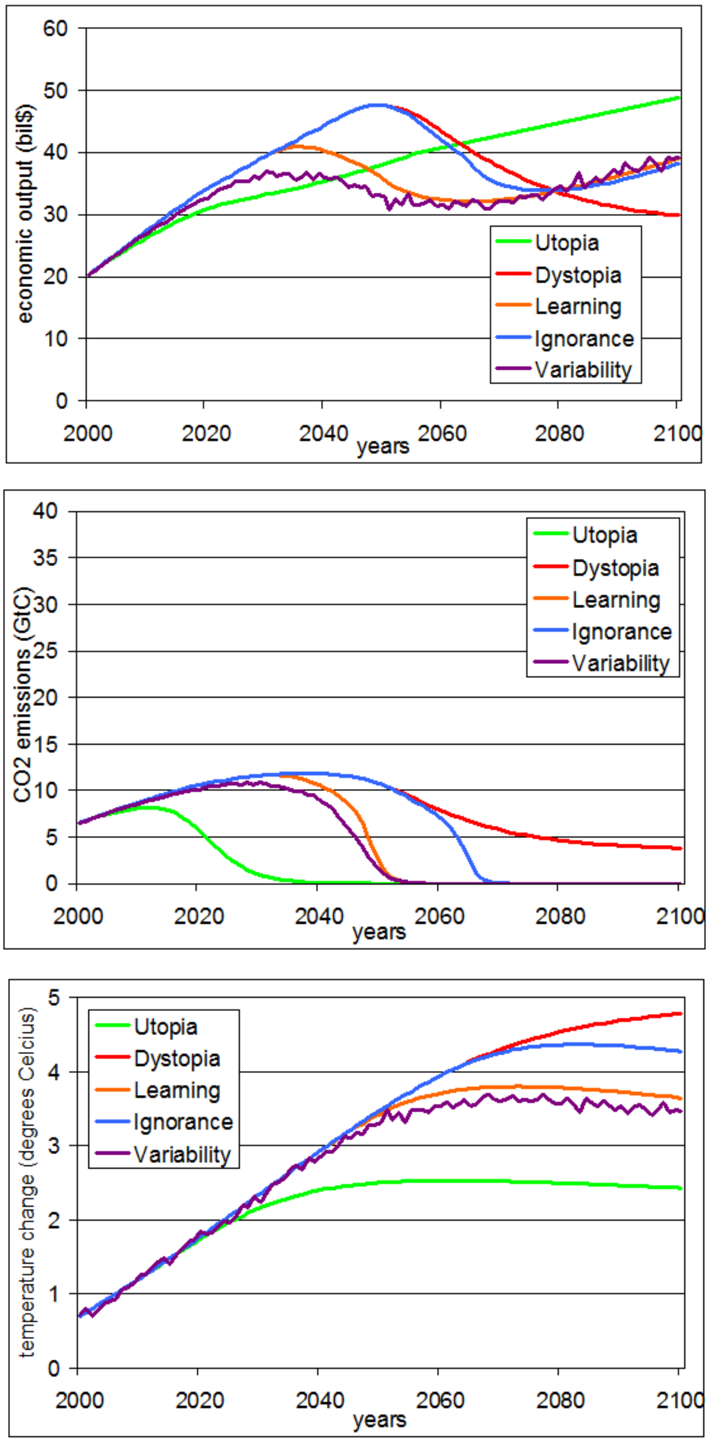


Figure 9.6: The effect of learning on economic output (A), $CO_2$ emissions and temperature change (C) compared with the utopian and the dystopian case. The lines in the shaded area represents the cases "learning" (a), "ignorance" (b) and "variability" (c).

For each type of functioning of the system a large number of simulation runs have been performed using different initial management styles. It is not surprising that highest economic outputs are derived when climatic change is small (Figure 9.7). Economic systems adapt to observed climatic changes. The success of adaptation varies with the initial institution.

What might be surprising is the fact that in a world where human-induced climate change does not occur, economic output over a century is higher when the dominant institution initially is community-based rather than hierarchic. The explanation is that a community institution is surprised much earlier than the hierarchistic one, so that the institution changed earlier to a market one. This also results in an early relaxation of $CO_2$ mitigation policy.

Based on these sensitivity runs, we can conclude that the market institution can lead to collapses of the system, while the community institutions can result in lost opportunities. The hierarchical institution is too slow to adapt to surprises leading to moderate collapses or moderate lost opportunities.

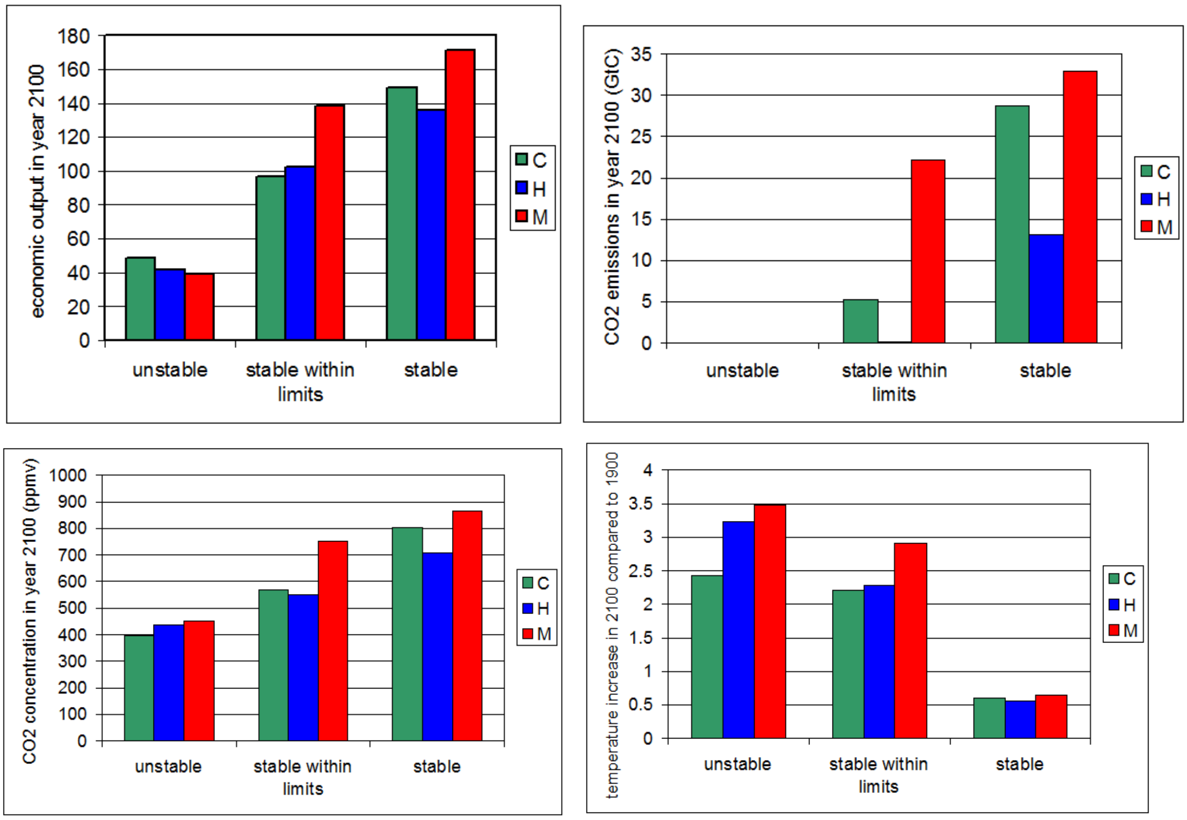


Figure 9.7: The average values of economic output (A) and temperature change (B) in 2100 for three possible worlds where agents do learn and adapt. For each possible world, the system can start with three different types of institutions: Community (C), Hierarchy (H) and Market (M).

What does this modeling exercise tells us? We can consider these scenarios as possible futures for different type of assumptions. Policies aimed at increasing the capacity for learning, adaptation and innovation are recommended. Bureaucratic control regimes are likely to reduce the ability to adapt. Current climate change policies are mainly focused on technical measures and institutional regimes to reduce or store $CO_2$. A resilient climate policy would invest more in new energy supply and demand technology, and social and physical infrastructure. In case our global ecosystem is sensitive to greenhouse gas emissions, effective learning and adaptation make the difference between a moderate climate change and catastrophic climate changes. To improve the resilient capacity of our global community, we should invest in three types of mitigation:

- precautionary: new technology and behavioral patterns can reduce the addiction to $CO_2$ and improve our ability to reduce emissions.
- adaptation: a certain degree of climate change seems to be unavoidable, which leads to improve the adaptive capability of ecosystems and economic sectors.
- reactive: Due to the unavailability of climate change, extreme events can occur, which can lead to important damage of ecological and economic systems. Policies need to be developed to react on such extreme events.

## Conclusion

Surprises are an essential and certain element of the future. To explore possible pathways of the future, surprises should explicitly be taken into account. With regard to resource management the consequences of surprises for resource managers and institutions are of interest. In this Chapter some examples to model possible reactions of resource managers and changing of institutions are discussed. The use of multi-agent models is central in the discussion, where agents here differ in their worldview of the system and the related preferred management style.

It should be clear that the modeling of changing perceptions of populations or changing institutions is in an embryonic state. The example of climate change shows the importance of the mixture of adaptive, precautionary and reactive policies. Precautionary policies are necessary to limit harmful surprises, but due to the current trends of change it is inevitable to prepare for system changes. Therefore adaptive policies are necessary to increase the adaptive capacity of nature and society. Finally, surprises can still lead to extreme events not prepared for, such that reactive policies need to be available.

Various type of models should be explored in the coming years to understand the interactions between worldviews, management and ecosystems. Improved understanding of these relations can improve our insights which types of policies and institutions are resilient in the longer term for both society and ecosystems.

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