3. ECONOMIC THOUGHT ON THE ENVIRONMENT AS APPLIED TO THE CASE OF GLOBAL CLIMATE CHANGE

3.1 INTRODUCTION

In the previous chapter it was argued that the development of economic thought did not provide an adequate framework for policy making on sustainable development. Following the development of Western philosophy, reality is perceived as including at least aspects of both substance and process. Reality also includes meta-physical aspects, but these are not further discussed in this thesis. The development of economic thought was on average mostly influenced by the substantivist view of reality, but could nevertheless be placed in the categories of substance and process economics.

As has been seen in chapter 2, no single theory could claim a monopoly on the truth. The challenge is to identify the elements that are most useful in specific complex and dynamic environmental problems, instead of attempting to optimise one particular interpretation of reality. It is further relevant to evaluate the importance of different theories on economics and the environment because of their influence on the policy-making approaches to sustainable development. In this study the focus is on environmental economics (including natural resource economics), ecological economics, neo-institutional economics and evolutionary approaches to economics (including institutional and co-evolutionary economics).

The objectives of this chapter are twofold; it will attempt to:

- identify the key elements of different economic theories on the complexity and dynamics of the natural environment
- evaluate the economic approaches mostly applied to the problem of policy making for climate change

This will be done through a discussion on the core concepts and the theoretical causal logic within each theory that, in turn, would provide information on how environmental management of complex and dynamic environmental problems, with specific reference to global climate change, is perceived to take place.

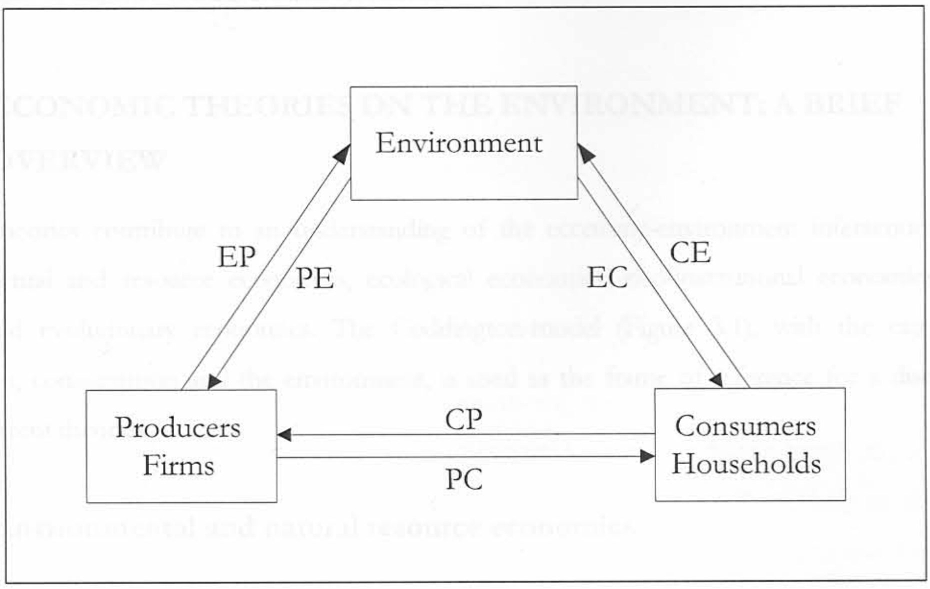
In section 3.2 the interactions between the economic and the environmental systems are represented as the interplay between production, consumption and the environment. In section 3.3 the various theories on economics and the environment are defined and discussed according to their approaches to production and consumption and the resulting impacts on the environment. In section 3.4 some aspects of complexity and dynamics are introduced into this conceptual framework, resulting in a broader interpretation of reality. In section 3.5 economic policy approaches to global climate change are assessed against this extended framework of economy-environment interactions.

3.2 INTERACTIONS BETWEEN THE ECONOMY AND THE ENVIRONMENT

The economic and the ecological systems interact in a variety of ways. In order to produce and consume goods and services one needs energy and material inputs (i.e. natural resources) from the natural environment. These economic activities are also often accompanied by pollution and waste streams that need to be absorbed in the natural environment. These economy-environment interactions have been described in detail in various contributions (Ayres & Kneese 1969; Coddington 1970; Fischer & Peterson 1976, 1977; Kneese, Ayres & d'Arge 1970; Pearce & Turner 1991; Perrings 1987; Siebert 1992; Solow 1974; van Ierland 1993; Winpenny 1991).

The focus in economics is on how to allocate limited resources among competing needs/desires, where this allocation process takes place through markets or other institutions. When trading takes place goods and services flow from producers to consumers, while labour and other inputs flow from consumers to producers (Gravelle & Rees 1992; Lombard, Stadler & Haasbroek 1987; Kamerschen, McKenzie & Nardinelli 1989). Nevertheless, it is pointed out in the contributions on economy-environment interactions that the natural environment is a limited resource and has to be included in economic analysis. Coddington (1970) offers a simple summary of economy-environment interactions through an expansion of this economic circular flow model of production and consumption to include the environment, as illustrated in Figure 3.1.

Figure 3.1 Economy-environment interactions



Source: Coddington (1970)

The environment provides services to human activities. As illustrated in Figure 3.1, these services are (Winpenny 1991:1-2):

- the provision of life-support systems (EC)
- supply of materials and energy (PE)
- the absorption of pollution & waste (EP and CE)

As illustrated in this Coddington-model (Figure 3.1), the main components in the economy-environment interaction are production, consumption and the natural environment itself. The different theories have different interpretations of the workings of the economy and the environment, and therefore would recommend different economic policies towards sustainable development. Environmental & resource economics, neo-institutional economics and ecological economics all share the perception that the environment is a stock of natural capital that depreciates, but with varying degrees of substitutability – the capital theory approach (Stern 1997; de Wit & Blignaut 2000). The appreciation of process, however, is inherent to the evolutionary approach to economics. The natural environment is perceived as being part of a dynamic world. One can therefore distinguish broadly between substantivist capital theory approaches (CTA) and evolutionary approaches in explaining the linkages between economics, human activities and the environment. In both broad approaches the important question is how many environmental services can be used sustainably in production and consumption processes and how many negative impacts can be mitigated in a sustainable way. The unsustainable use of materials and energy (i.e. degradation and depletion (DD)) or the stream of pollution and waste (PW) can occur as a result of the human activities of production and consumption and may lead to negative environmental feedbacks.

3.3 ECONOMIC THEORIES ON THE ENVIRONMENT: A BRIEF OVERVIEW

Various theories contribute to an understanding of the economy-environment interactions, namely environmental and resource economics, ecological economics, neo-institutional economics (i.e. the CTAs) and evolutionary economics. The Coddington-model (Figure 3.1), with the categories of production, consumption and the environment, is used as the frame of reference for a discussion of these different theories.

3.3.1 Environmental and natural resource economics

Definitions

Environmental economics is an applied field of neoclassical economics. Various studies give comprehensive accounts of environmental economics (Cropper & Oates 1992; Pearce & Turner 1991; Turner, Pearce & Bateman 1993; Goodstein 1995a; Baumol & Oates 1988). Environmental economics can be distinguished by the concepts of opportunity costs, individual choice, economic efficiency, the existence of externalities, and the arguments in favour of private property rights. **Opportunity cost** is the cost of the next best alternative which is foregone/sacrificed. Every decision involves some explicit or implicit costs. For example, the opportunity costs to control greenhouse gases (GHGs) is foregone investment in other investment areas such as education or housing. The obligations towards the environment could therefore *not* [be treated as] *rare side-issues, but … endemic and pervasive to the world in which we live* (Pearce 1998:31). According to mainstream economic theory, free **individual choice** would lead to the most **efficient** economic outcome. Other criteria such as equity concerns and long-term sustainability could in principle be included in individual preference orderings, but through behavioural changes (Wolfson 1992:66). If the preferences are imposed on the general public through government intervention, economic efficiency will not be achieved. When opportunity costs are not well-defined, choices are misinformed. In such cases **externalities** may occur, meaning that one agent's actions have a positive or negative effect on another agent's actions, for example the release of GHGs in a particular region would have an effect on global climate change impacts in another region. The required solution is the allocation of **private property rights** (Baumol & Oates 1988).

Natural resource economics is concerned with **natural** resources in scarcity (Kneese 1989:282). It helps to understand the causes of depletion of non-renewable and critical zone resources and the overexploitation of renewable resources (Hyman *et al.* 1988:67). The primary focus is on the optimal depletion path through time or across space for non-renewable resources (Hotelling 1931; Kneese 1995:7)[11] and on the optimum time to use renewable resources (Kneese 1995:8; Dasgupta 1982).

Both environmental and resource economics are extensions of neoclassical economics, bridged through welfare economics. Welfare economics is the branch in economics that is concerned with the nature of policy recommendations that economists can make (Mansfield 1988:466). In section 2.5 it was pointed out that welfare economic approaches are controversial as the collective choice process does not lend itself easily to a reductionist decision rule such as economic efficiency.

Environmental and resource economics are both based on neoclassical economics and share the same underlying philosophy. Resource economics focuses on the optimal rate of exploitation and environmental economics on the optimal level of pollution and waste. Resource economics focus more on the inputs to production, and environmental economics on the residuals of both production and consumption. For the purposes of this thesis the term environmental economics will include both environmental and resource economics.

Production theory

Production, consumption and exchange are the building blocks in mainstream micro-economics (Gravelle & Rees 1992; Mansfield 1988) and in an aggregated sense also of macro-economics (Dernburg 1986). Firms are responsible for production, and households for consumption. Exchange happens in markets. In a neoclassical sense production is *the activity of combining goods and services called inputs, in technological processes which results in other goods and services called outputs* (Gravelle & Rees 1992:166). On the production side, the focus of neoclassical economics is on how *a profit-maximising firm will combine inputs to produce a given quantity of output* (Mansfield 1988:187). The starting point is *the problem of minimizing the cost of producing a given level of output subject to technological constraints* (Gravelle & Rees 1992:180). The standard assumptions are substitutability of inputs and economies of scale[12].

Resource economics is an extension of neoclassical production theory. Barnett and Morse (1963) perpetuated the view that resources used as inputs in production processes were not scarce. However, increased concerns on absolute and relative resource scarcity brought the realisation that inputs might not be infinite and have to be exploited optimally (Dasgupta 1982). Despite the realisation that all economic activity is ultimately based on resources found in nature, *natural resources find little room in economics discourses* (Dasgupta 1991:26). The standard reaction was to incorporate resources into standard

[11] The key concept in the Hotelling theory of optimal resource depletion is that depletion is an activity in which the opportunity cost of production today is production at some future date (Perrings 1987:133).

[12] The economy of scale is an indication of the relative change in output due to an increase in inputs. Decreasing and increasing returns to scale are not explained by neoclassical economic theory. The question of returns to scale is treated as an empirical question that must be settled case by case (Mansfield 1988:177). The point, however, is that output will always increase with increased inputs, but at different rates.

Cobb-Douglas and CES production functions. Natural resources are therefore treated as an additional input in the production function (Solow 1974).

Consumption theory

In neoclassical micro-economics attention is focused on individual decision-making units, one of the most important of which is the consumer (Mansfield 1988:51). The purpose of consumer theory is firstly to characterise the bundle of goods which will be chosen and secondly, to predict how the optimal choice will change in response to changes in the feasible set (Gravelle & Rees 1992:68). The chosen bundle of goods can be illustrated through individual demand curves.

Environmental economics is an extension of neoclassical consumption theory. The subject field of environmental economics is individual choice with respect to pollution and waste emissions because of economic activities. Unrestricted consumption is the key measure of value addition. In essence, environmental problems are examples of the economic choice between one form of consumption and another (Jones & Hollier 1997:47) – a choice between consuming environmental services or the products and benefits derived from consuming these environmental services.

Impacts on the environment

The degradation of resources can best be understood against the background of a clear resource classification. The environment in the Coddington-model (Figure 3.1) can be classified as being natural and environmental resources. Natural resources are either renewable or non-renewable. Examples of renewable resources are solar radiation, ocean currents, hydrological cycle, wind and water. Non-renewable resources are minerals such as metals, coal, oil, et cetera. Living resources such as plants, fish and game are renewable, but have the potential to become non-renewable. The mismanagement of non-renewable resources, therefore, is much more serious since the utilisation of essential environmental services might be unsustainable.

The ownership structures of natural and environmental resources are also very different. Natural resources can be either privately, publicly or commonly owned, while environmental resources are almost always publicly or commonly owned. The type of ownership forms the basis of economic and social approaches to sustainable development. A public good is one in which each individual's consumption leads to no subtraction from any other individual's consumption of that good (Samuelson 1954). There are naturally **public bads** as well as goods – examples are air and water pollution (Krutilla & Fisher 1985:23). Common property resources permit neither exclusion nor discrimination with respect to its access, often referred to as **open access** resources (Krutilla & Fisher 1985:20). Various studies have shown that open access leads to an overexploitation of the common property resource (Gordon 1954; Scott 1955; Hardin 1968; Haveman 1973). Table 3.1 illustrates whether different property rights regimes meet the normative criteria for (economic) efficiency.

Table 3.1 A typology of property rights regimes and conditions for efficiency

	Open Access	Common Property	Private Property	State Property
Universality	No	Defined for the group	Yes	No
Exclusivity	No	Defined for the group	Fails in presence of externalities and public goods	No, but non-nationals excluded
Transferability	No	Applies for the group	Yes	No
Enforce ability	No	Yes: legal and social sanctions	Yes: legal and social sanctions	Yes: legal sanctions
Overall efficiency	Very low efficiency no incentive to conserve	Efficient in many regimes, but inherent risk of breakdown	Efficient but market failure occurs in presence of externalities and public goods	Inefficient often due to government failure

Source: Pearce *et al.* (1994:20)

Table 3.1 illustrates that private property rights are most likely to lead to better environmental management as measured against the norm of (economic) efficiency. Most literature in environmental and resource economics tend to emphasise this point (Pearce *et al.* 1994). Neoclassical economists emphasise well-defined property rights as an underlying prerequisite to well-functioning markets. Markets organise the exchange of control where property rights define the nature of control (Gravelle & Rees 1992:513). A decay of natural resources or emissions of waste is viewed as an instance of market failure, so-called negative external effects, and relatively easy to overcome. Due to these externalities, private costs differ from social costs (Turvey 1963; Coase 1960). The primary function of property rights is to guide incentives to achieve greater internalisation of externalities (Demsetz 1967; Coase 1960), thereby alleviating DD&PW (degradation and depletion, pollution and waste). The environmental economic research agenda on DD&PW is therefore focused on the internalisation of externalities through well-defined private or public property rights and market prices (Baumol & Oates 1988).

3.3.2 Ecological economics

Definitions

Ecological economics addresses the relationships between ecosystems and economic systems in the broadest sense (Costanza 1989:1; Costanza *et al.* 1997a:51; Costanza *et al.* 1997b; Daly 1996; Krishnan, Harris & Goodwin 1995; Jansson 1994; Barbier 1993)[13]. In contrast with environmental economists, ecological economists have opted for a more cautious approach to maintain the life-support systems and the aesthetic qualities of the environment (Costanza 1989:3). It includes neoclassical environmental and resource economics, environmental impact studies and conventional ecology as subsets, but encourage new ways of thinking in bridging the gaps between ecological and economic systems (Costanza *et al.* 1997a:50). The central question in ecological economics is one of biophysical limits and the ability of technology to circumvent them.

It should be noted that there is a debate on different approaches in ecological economics. One can differentiate between two broad schools of thought within ecological economics: those who work within the parameters of neoclassical economics (the Beijer Institute) and those who work in a more political programme (the International Society for Ecological Economics) that focuses on the *equitable distribution of resources and property rights within the present generation of humans, between the current and future generations, and between humans and other species* (Masood & Garwin 1998:426-7).

Ecological economics is a young branch of economics with no clear-cut theoretical framework. For the purpose of this thesis ecological economics is treated as an extension of neoclassical economics, but with an inclusion of biophysical limits. This means that the environment is still treated as natural capital, but with limitations on the substitutability between natural and other types of capital (e.g. man-made, human and social capital). For the purposes of this thesis, the focus of some ecological economists on a systems understanding and process has been included in the evolutionary approaches to economics (Faber, Manstetten & Proops 1996; Faber & Proops 1990).

Considering this background it would be difficult to shape an outline of the ecological economic research agenda. However, according to Costanza *et al.* (1997a:79-80), ecological economists have consensus on the following:

- the vision of the earth is a **thermodynamically closed and non-materially growing system**, with the human economy as a subsystem of the global ecosystem. This situation implies limits to biophysical throughput of resources from the ecosystem, through the economic subsystem, and back to the ecosystem as wastes;
- a future vision of a **sustainable** planet with a high quality of life for all its citizens within the material constraints;

[13] See also contributions in the journal *Ecological Economics*.

- the recognition that in the analysis of all complex systems like the earth at all space and time scales, fundamental **uncertainty** is large and irreducible and certain processes are **irreversible**, requiring a fundamentally precautionary stance; and
- that institutions and management should be **proactive** rather than reactive, which would result in simple, adaptive, and implementable policies based on a sophisticated understanding of underlying systems which fully acknowledge the underlying uncertainties.

Production theory

Production is the starting point in ecological economic theory (Christenensen 1989; O'Hara 1997). The neoclassical factors of production (i.e. capital, labour) are exchanged for *materials, energy, information flows, and the physical and biological processes that convert, transmit, or apply them* (Christenensen 1989:8). Production is subject to the laws of thermodynamics and the complementary nature of energy and capital. It is inherent that production will be inefficient because of the production of waste. Including spatial and temporal aspects, production will always lead to degradation of natural resources and the environment. This pessimistic view is incompatible with the neoclassical introduction of natural capital into the production function: *…although resources are now recognised as necessary for production, the amount of resources needed for any given level of output can become arbitrarily small, approaching zero, as long as capital and labour are substituted in sufficient quantities. And it is implicitly assumed that the extra capital and labour can be produced without extra resources!* (Daly 1996:64). Ecological economists place the underlying biophysics and the non-substitutability of natural and man-made capital central in production theory[14].

In summary, the main differences between the ecological and neoclassical approach to production are the following:

- The question of **substitutability** between inputs. Based on the conceptual discussion on natural, critical capital, substitution of natural capital for man-made capital can only happen up to the point where further loss of natural capital will threaten life-support systems.
- The adherence to both the **material balance** and **entropy** principles. Neoclassical economics at best adheres only to the material balance principle, while ecological economics, in theory, adheres to both. (For a further discussion see section 3.4.3).
- Related to the first two: neoclassical resource economics perceives value to be added in production through the optimal extraction of resources according to the Hotelling rule. Ecological economics perceives value to be added when both optimal extraction of resources is achieved and the impacts of increased disorder are spelled out.

- Neoclassical economists are generally grouped as **optimists**, while ecological economists are perceived as being **pessimists**.

It can be concluded that neoclassical production theory is useful in a setting of abundant natural resources and a sufficient assimilative capacity of the environment, implying no threat to critical life-support functions (see also Pearce (1976) in the context of cost- benefit analysis). The relative impacts of increased disorder, as implied by the entropy law, in such cases are negligible. The ecological economic approach to production is more useful when there are biophysical limits on production.

Consumption theory

Ecological economists view consumer choices as being secondary to production. Not only the value added to the flow of natural resources through capital and labour can be consumed, but also the value that was added by nature before it was imported into the economic subsystem (Daly 1996:65). If these values are consumed without being accounted for, the outcome will be unsustainable. Consumption is not regarded as a measure of welfare as it is bound by biophysical limitations (Daly 1996).

Impacts on the environment

Ecological economists view environmental degradation as a natural entropic law, aggravated by the actions of human beings. DD&PW is pervasive and cannot be treated as an incidental externality. DD&PW can become a serious threat when ecological thresholds are surpassed and further actions would threaten life-support systems themselves. The recommended course of action will be to enforce compliance within certain thresholds. This approach is applicable in the setting of critical non-renewable resources and where renewable resources have the potential to become non-renewable.

The laws of thermodynamics (see section 3.4.3) have important implications for natural resource and waste/pollution management. Given the first law, the focus should be on optimising:

- the environmental degradation during extraction of resources for inputs,
- the absorptive capacity of the environment, and
- the amount of waste produced.

There is scope for optimal management of environmental degradation. The absorptive capacity of the environment cannot be substantially increased. Matter cannot be created, only combined in different ways. The amount of waste can be optimised through regulation on dumping of wastes, through assessing the true costs of disposal and through higher levels of recycling. The second law of

[14] Some ecological economists have linked production, apart from biophysics, to its social context as well (see O'Hara 1997). The hidden costs of households have to be taken into account as well. O'Hara (1997) stated clearly that the technological production process could only be a sustaining process when social and ecological factors are placed into its context.

thermodynamics implies that these recommendations for resource and pollution management have to take account of the decrease of useful energy and where and when increased disorder is taking place. Increased disorder can occur geographically within the boundaries of the earth or within the planetary system. Long time lags between degradation, depletion and effects might initially hide increased disorder. Table 3.2 summarises how the management of natural resources degradation and pollution should be approached in an ecological-economic perspective, taking both laws of thermodynamics into account. Spatial and temporal factors become more important if entropic boundaries and increased disorder over time have to be included in approaches to environmental management. The depletion and degradation of, mostly area-specific, natural resources have to be managed for optimal levels of extraction over a time path, but the irreversible impacts of pollution and waste on ecosystems could create disorder across both time and space. Ecosystems are complex and the impacts of increased disorder over time and space cannot be measured easily. The important message from an ecological-economic perspective is that optimal resource degradation & depletion and optimal waste/pollution levels (taking the first law of thermodynamics into account) are necessary – but not sufficient – to ensure a sustainable flow of environmental services.

Table 3.2 The laws of thermodynamics and natural resource and environmental management

Laws of thermodynamics	Natural resource degradation and depletion	Pollution and waste
First law: Total amount of mass/energy is conserved in all processes.	Optimise extraction of resources.	Optimise absorptive capacity of environment. Optimise amount of pollution/waste produced..
Second law: Entropy increases in any irreversible process, i.e. the amount of useful energy decreases.	Optimise extraction of resources.	Define boundaries of entropy. Evaluate impacts of increased disorder across time and space.

Source: Own analysis

3.3.3 Neo-institutional economics

Definitions

According to Eggertsson (1990) institutional economics encompasses a broad field and could possibly be categorised in the old, new and neo-institutional economics. The old institutional economists (Veblen 1934; Commons 1934) concentrated on a methodological criticism of the neoclassical paradigm mainly from an evolutionary perspective, thereby providing much descriptive material. The new institutional economics rejects some elements of the hard core of neoclassical economics, such as the rational-choice model (Eggertsson 1990:6). Neo-institutional economics follows the neoclassical hard core, but include subsets such as the property rights school, transaction cost economics, the new economic history, the new industrial organisation, the new comparative economic systems and law and economics (Eggertsson 1990:6).

Most neo-institutional approaches in this category have the following core concepts in common (Eggertsson 1990:6-7):

- an analysis of the constraints of **rules and contracts** in exchange
- the introduction of **transaction costs** to the analysis
- an easing of the two-dimensional study of prices and quantity to include the implications of **economic organisation** on economic outcomes

Rules and contracts stipulate the terms of exchange of goods and services. The contractual terms specify what rights are being transferred and on what terms. Private property rights are one way to structure the terms of exchange of goods and services. The neoclassical concept of private property is extended to entitlements, thereby including well-defined common and public property rights (Bromley 1985). The costs arising when agents exchange ownership rights to economic assets and enforce these rights are the **transaction costs** that should also be included in the neoclassical concept opportunity costs (Eggertsson 1990:14). The market is one type of **economic organisation** for the management of natural and environmental resources. Mainstream economics has primarily focused on the examination of idealised rules governing market exchange (Eggertsson 1990:4). However, other institutions could also play a role in the organisation of production, consumption and the impacts on the environment. The relative economic advantage of alternative forms of economic organisation will determine which organisational structure will survive.

Production theory

In the neo-institutional approach it is attempted to understand the so-called **black box** in production organisation. Institutional restrictions and transaction costs are added as constraints to production. The structure of property rights affects individual behaviour and output through influencing the range of internal rules of the game available to a particular organisation (Eggertsson 1990:127). The strength of associations, relationships and institutions determine the context of production, which has a direct effect on productivity itself. A production frontier can shift outwards due to the strengthening of the property right structure itself. Value is added through efficient allocation of property rights, low transaction costs and high managerial efficiency. In summary, the neo-institutional production theory differs from the neoclassical and ecological economic approaches in the following ways:

- The focus is on the structure of property rights as an input in the production function, rather than on capital and labour as such.

- There may or may not be ecological limits in production, but these limits can ultimately be ascribed to an ill-defined structure of property rights.

Consumption theory

Unlike environmental economic theory, neo-institutional economists do not place consumption and choice central to their analysis. The emphasis is, like in production theory, on the additional constraints of institutional restrictions and transaction costs on the individual maximisation of utility (de Alessi 1983:64). The consumption of environmental services is, like in production theory, a function of the structure of property rights.

Impacts on the environment

Both neoclassical and neo-institutional economists view DD&PW as an ownership problem. Neo-institutional economists view DD&PW as institutional failure or poor technology choice (Goodstein 1995b; Söderbaum 1987; Swaney 1987a, 1987b; Dietz & van Straaten 1992). Institutional failure may occur through the initial distribution of property rights, or the institutional setting, and the intricacies of existing property institutions or the development of property rights over time. This vindicated a relatively new field of research in neo-institutional economics, concentrating on property rights, transaction costs and contracts (Eggertsson 1990), contrary to the neoclassical position of a **particular institutional setting** (Livingston 1987:292). Well-functioning institutions are measured against low transaction costs and it does not matter primarily whether property rights are privately, publicly or commonly owned.

This multifaceted approach to property rights calls for a more complex treatment of DD&PW (Bromley 1978). Bromley (1978) saw such increased complexity in two areas. Firstly, to recognise a variety of **entitlements**, deepening the concept of property rights and secondly, to admit that each interdependent situation can be characterised by a **variety of attributes**. Apart from this variety of interdependencies, it becomes critical if (Bromley 1978:52):

- the interference is potentially damaging to human health
- the interference is potentially damaging to ecological integrity
- there are significant third party effects
- there is an empirically ascertainable damage function (entitlements should differ to take these interdependencies into account)

This variety of entitlement attributes will influence the strength of the property rights structure.

According to neo-institutional economists, technology is not exogenous and smooth substitution is not possible (Goodstein 1995b:1032). Tomorrow's environmental deterioration or improvement is highly dependent on the technologies chosen today.

3.3.4 Evolutionary approaches

Definitions

Although both new and neo-institutional economics stimulated a lot of thinking on the theory of the firm and the transaction costs theory, the main critique from within the institutional school itself is aimed at its static analysis. This critique comes from the old institutional economic school, organised within the broader evolutionary economic schools of thought. Recent texts on evolutionary economics include Hodgson (1999); Day & Chen (1993); Faber & Proops (1990); Metcalfe (1998) and Anderson (1994). According to Hodgson (1999:127-128), the term evolutionary economics is applied to a wide variety of approaches:

- institutionalists in the tradition of the old institutional economic school, often using the terms evolutionary and institutional as virtual synonyms[15]
- work influenced by Joseph Schumpeter[16]
- the approach in the Austrian school of economists, following the work of Charles Menger (1840-1921) and Friedrich von Hayek (1899-1992)
- the economics of assorted writers such as Adam Smith (1723-1790), Karl Marx (1818-1883) and Alfred Marshall (1842-1924), often described as evolutionary in character
- evolutionary game theory, a recent prominent development in mathematical economics
- work done on complexity theory in institutions such as the Santa Fe Institute in the United States, involving applications of chaos theory and computer simulations (Arthur, Durlauf & Lane 1998; Arthur 1989; Waldrop 1994)

These different approaches are still very much in development and it would be a premature attempt to extract a theoretical evolutionary economic framework (Hodgson 1999:154). The approach is to seek the elements of mutual consensus between these approaches relevant to the development of an integrative framework on economics, human activity and the environment. The following key elements are suggested:

- The evolutionary paradigm attempts to explain the **changing** reality.
- The economic system, whether of the world or in its parts, is seen as a continuing process in space and time (Boulding 1981). Where most people, in the short-term, interact in accordance

[15] Publications mainly in the *Journal of Economic Issues* and the *Journal of Economic Behaviour and Institutions.*

[16] Publications mainly in the *Journal of Evolutionary Economics.*

with the mechanistic and reductionistic worldview, the evolutionary model incorporates longer-term **feedbacks** into the economic system.

- In the field of evolutionary economics, policy development and application have particularly focused on **technological progress** and **innovation** (Nelson & Winter 1982; Dosi *et al.* 1988). Innovation is an action that has not been carried out earlier, i.e. an action involving **novelty** (Witt 1993:92)[17]. According to Witt (1993), experience shows that novelty occurs in all the phases of the trial and error process, from invention to the carrying out of innovative action. Although some innovations may be more predictable than others, the important point is that optimal choice cannot be made since all alternatives are not known **ex ante**. Previously unknown possibilities, generated by innovations, occur all the time.
- In an evolutionary approach the agent is perceived as not maximising his/her behaviour. Behaviour depends on many extra-economic constraints and rules perceived by agents (Dosi *et al.* 1988). Agents are **continuously learning** these **constraints and rules** which function as the driving mechanisms both for coordination and change. These changes are not necessarily gradual; crises may occur. Long-term changes can therefore not be explained through market coordination alone, but are subject to a broader teleological process.

Co-evolutionary economics builds on this evolutionary paradigm, considering the co-evolutionary process and emphasising the relationships and interdependencies between natural, social and economic systems (Norgaard 1994a, 1994b, 1988, 1985, 1984; Gowdy 1994; van Jaarsveld 1996, van Jaarsveld *et al.* 1996)[18]. Development, when defined as the accumulation of capital, assumes a constant metric, which the co-evolutionary vision denies (Norgaard 1994a:218). In the co-evolutionary framework, development is defined more broadly, over longer periods, and helps us to see how these perspectives themselves are evolving constructions of a larger process.

Production theory

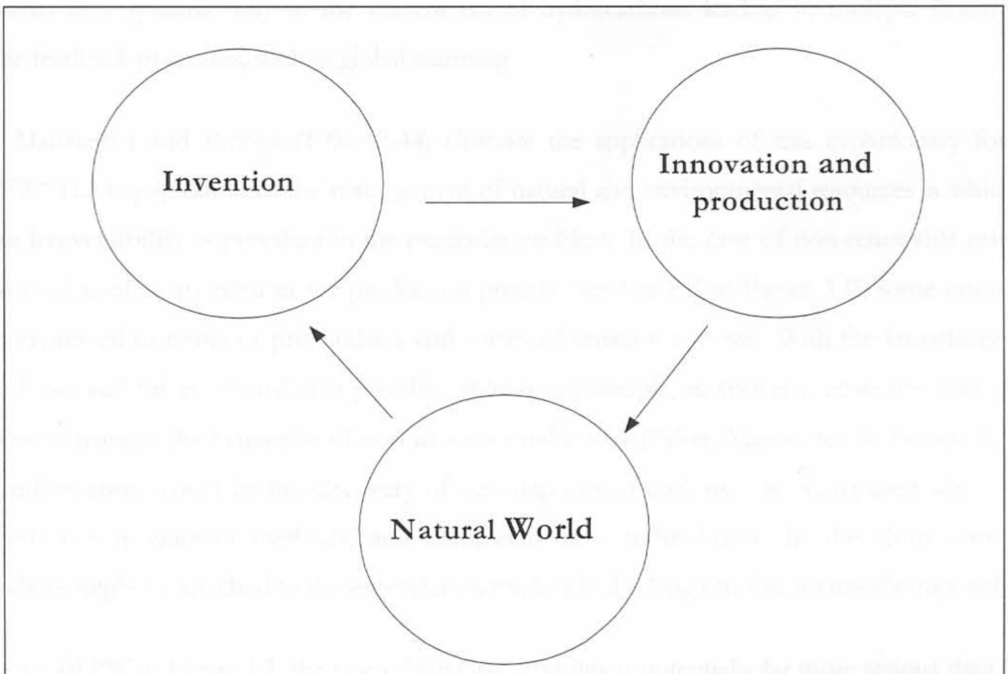
Not surprisingly, the evolutionary approaches do not adhere to the capital theory approaches to economy-environment interactions. Evolutionary economists have mostly contributed on the linkages between the dynamic concepts of technological development, innovation and production. In these approaches the production **process** is considered very important (Faber & Proops 1990:115). When the concept process is introduced in the production model, historical time is endogenised (Faber & Proops 1990:123). Following Figure 3.2, some analysts working in the tradition of evolutionary economics have

[17] In contrast to this view, Schumpeter (1934) defines innovation as the carrying out of ideas which have been around for some time and confines the emergence of novelty to the realm of invention which he considers to be irrelevant to economics (see Witt 1993:92).

[18] See also articles with a co-evolutionary viewpoint published in journals such as *Ecological Economics* and the *International Journal for Sustainable Development.*

referred to the natural world in their production models. The constraints imposed by the natural world would lead to new inventions. Innovation is the bringing into use of these newly invented techniques. Faber and Proops (1990:5) refer to this interpretation of production as the economy-environment **triangle of causation** as pictured in Figure 3.2. The important point is that biophysical limits in the natural world could be a starting point of invention and innovation.

Figure 3.2 The triangle of causation: invention, innovation and the natural world



Source: Faber and Proops (1990)

The interplay between biophysical limits and innovative ways to overcome those limits, are aspects that have not been treated adequately in the Coddington-model of economy-environment interactions. In section 3.4.5 these aspects are further discussed as extensions to the Coddington-model.

Consumption theory

The same approach that applies to production theory is relevant for consumption theory. The process and history of consumption have received more attention than the neoclassical estimation of the optimal choice of **consumption bundles**. The focus in evolutionary economics is instead to assess behavioural shifts over time.

Impacts on the environment

The evolutionary economic focus on the process of changing realities implies a more dynamic approach to DD&PW than the other capital theory approaches. The argument is that a re-definition of property rights or the enforcement of environmental standards will be of little help if incremental environmental damage could possibly lead to a collapse of the system itself (Ring 1997). Thus, in case of chronic or pervasive environmental problems, a process-orientated approach to DD&PW is needed - one approach being an analysis of the **patterns of development**. Rather than relying on a **simple counting exercise**, the analysis should point to all the options available to the decision makers (Söderbaum 1987:152). For example, Norgaard (1988) argues that the world at large is on an unsustainable path. He analyses the pattern of world development coming from early history where mankind did not disturb ecosystems in a systemic way to the current era of hydrocarbons leading to multiple negative and systemic feedback processes, such as global warming.

Faber, Manstetten and Proops (1996:42-44) illustrate the applications of this evolutionary focus on DD&PW. The key question to the management of natural and environmental resources is which **type of time irreversibility** is prevalent in the particular problem. In the case of non-renewable resources, such as coal, used as an input in the production process (see line PE in Figure 3.1), some information can be expressed in terms of probabilities and some information is novel. With the knowledge about stocks, flows and prices of coal, it is possible, at least in principle, to conceive economic and political measures to manage the extraction of coal in a reasonable way (Faber, Manstetten & Proops 1996:43). Novel information would be the discovery of new deposits of coal, new recycling methods, new and more efficient production methods, and completely new technologies. In the short term some probabilities might be attached to these developments, but in the long run this is virtually impossible.

In the case of PW in Figure 3.1, the type of time irreversibility is potentially far more serious than for the problem of resource depletion. PW are often not detected at the start of economic activities; it is often perceived not to be harmful when detected; when it is recognised to be detrimental the dose-damage functions are unknown, and by the time one really knows what to do it may be too late (Faber, Manstetten & Proops 1996:44). The surprise factor lies in the changing linkages between economic activity and the environment. Given the uncertain character of these relationships, the true price, after internalising for the effects of PW, would only be knowable **ex post**. In summary, DD would generate scarcity, which is reflected in market prices, which in turn will generate novelty. However, PW are themselves a source of novelty, and would generate slowly, and sometimes not at all, a search for market pricing to encourage the reduction of emissions and waste streams (Faber, Manstetten & Proops 1996:44). This dynamic approach to economy-environment interactions is per definition not included in the Coddington-model, and some elaboration is needed.

3.4 ASPECTS OF COMPLEXITY AND DYNAMICS IN ECONOMY-ENVIRONMENT INTERACTIONS

It was pointed out in Chapter 2 that there is no truism on a physical level (as opposed to the meta-physical level) that includes or excludes any of these normative criteria by definition. The second-best appeal to the human understanding of the nature of reality reveals that a theoretical model that approximates reality should at least include aspects of both substance and process. This means that it cannot be stated unanimously that the different theories on economy-environment interactions are mutually exclusive. Whereas evolutionary approaches focus on the broader process of economy-environment interactions, neoclassical, ecological and neo-institutional approaches focus on the definition of the aspects of production, consumption and environment in these interactions. Therefore, the challenge of any integrative framework for evaluating economy-environment interactions that includes aspects of both substance and process, would be to demonstrate where the different theories are most applicable and to what degree. Throughout the discussion of the Coddington-model in section 3.3, it has been pointed out that the framework is limited, especially with regard to the dynamic aspects of the evolutionary economic theory, the complexity of ecosystem functioning and the potential of irreversible impacts. According to these interpretations there are important feedback mechanisms that cannot be ignored in a study of economy-environment interactions. The first step is therefore to include those aspects describing reality that are excluded from the Coddington-model and are likely to have an impact on policy-making approaches for sustainable development. The second step is to develop an approach to policy making for sustainable development that takes account of these added complexities to economy-environment interactions. The first step is attempted in the next section, while the second step is the focus of the remainder of the thesis.

The aspects to be included in the Coddington-model have been highlighted in the introduction to the economic theories on the environment in section 3.3 above and elaborated on in this section. The following issues are further discussed as extensions of the Coddington-model on economy-environment interactions:

- the values underlying the theories on economics and the environment
- ethical and social limits
- biophysical limits and the laws of thermodynamics
- risk, uncertainty and irreversibility
- process and time
- technology and innovation

3.4.1 Values and the environment

In section 3.3 it was pointed out that unlimited production and choice are key concepts in neoclassical theory, biophysical and social limits on production and consumption are key concepts in ecological economic theory, and property rights structures and transaction costs are key concepts in neo-institutional economic theory. The question which theory is the best approximation of reality cannot be answered without reference to an evaluation framework that has to be based on some predefined norm. Therefore, before discussing other aspects of economy-environment interactions, it is important to understand what normative **a priori** values are used in the different theories on the economy and the environment.

What constitutes value for the different theories on economics and the environment? The importance of this question is that it would influence the economic policy approaches toward sustainable development (Blignaut & de Wit 1999). In Chapter 2 it was argued that value-free social sciences do not exist. Economics is partly ideology, and a separation of the positive from the normative in developing economic theory is contradictory. Economic efficiency is in effect a normative choice, and does not represent scientific objectivity. A comparative analysis of the value-concepts for the different theories on economics and the environment would yield some insights into the reasons why some policies are recommended by different theories on the economy and the environment.

In Table 3.3 an overview is given of the fundamental value principles from the different economic theories on the environment. The Physiocrats and earlier classical economists, such as Thomas Malthus (1766-1834) and David Ricardo (1772-1823), believed that all surplus can be derived from the productive power of land. Post-Ricardian classical economists took a broader approach to the economy, and included production factors such as labour and capital (Christenensen 1989). Subsequent developments in neoclassical theory shifted the focus on the scarcity of the production factor as the principle of value to one where the exchange between actors determines value. In this theory prices as determined through market processes have become the best indication of value. In reaction to the rise of environmental problems, which often do not have market prices or are underestimated in market prices, environmental economic theory aims to impute the value of environmental quality in market prices. The contribution from neo-institutional economics is that the transaction costs of exchange are also included in either the neoclassical exchange value or the environmental-economic imputed exchange value. Like the classical economists, the ecological-economic approach takes production as the starting point of economic theory. The economic rent flowing from the production of natural and environmental resources, including the value of nature itself and not only the costs of production factors, is perceived to be the principal source of value, with an emphasis on the long-term maintenance of natural and environmental systems. In evolutionary approaches value is not rooted in an unchanging principle, but is subject to the reality of change itself. Although not representative for all evolutionary economic theories, an attempt has been made to derive a set of principles for so-called social values. The old institutional school, treated as a subset of the evolutionary approach in this dissertation, developed these principles.

Table 3.3 Economic theories and fundamental principles determining value

Economic Theory	Fundamental principle of value
Classical economics	Scarcity of production factor (land, labour and capital)
Neoclassical economics	Real exchange value
Environmental economics	Imputed exchange value
Neo-institutional economics	Real or imputed exchange value with inclusion of transaction costs
Ecological economics	Economic rent of natural and environmental resources
Evolutionary economics (especially old institutional school)	Instrumental principles of social value, focusing on the continuity of human life

Source: Adapted from Blignaut & de Wit (1999).

The point illustrated in Table 3.3 is that different theories have very different fundamental principles determining value. It was mentioned in section 2.5 that **economic efficiency** is the normative choice for value in the neoclassical-economic approach (Bromley 1991:207). This also applies to environmental-economic and neo-institutional approaches, as they are based on neoclassical-economic approaches. Both the classical-economic and ecological-economic theories do not fundamentally rely on exchange values, and therefore, on economic efficiency as determined by market processes. The classical economists thought in terms of the general well-being of people and the usefulness of policies to address their problems. The individual utilities of people were not aggregated to a social welfare function, as in new neoclassical welfare economics[19]. It is suggested that the normative starting point of the classical economists be described as one of **productive efficiency** (efficiency in production factors). Ecological-economists have developed the similar normative criteria of **sustainability** (Costanza 1991). The capital-theory approaches have in common that they attempt to integrate the natural environment in a substantivist order or structure of analysis. In the evolutionary approach change in itself is perceived

[19] The development of new welfare economics triggered a huge debate in economics. Robbins (1932), heavily reliant on positivism of those times, published his influential book *An Essay on the Nature and Significance of Economic Science*, where the focus is on the relationships between individuals – how in fact allocation works. The concept utility changed in meaning from the usefulness in old welfare economics (general well-being of the people) to desires (individual preferences) in the new welfare economics. Knight (1921) recognized this distinction between individualistic economists and those who believe in a planned economic system. Keynes (1917) favoured the latter and saw economists as social philosophers. From both points of view there is agreement that the role of economic theory is to understand the economy we in fact have. The difference is that interventionists would add in order to change it and non-interventionists would add in order mostly to appreciate it. Attempts to bridge the gap between Keynes and mainstream economics have become known as the search for micro-foundations. Up to now such a foundation is, however, wanting in as many respects as macroeconomics itself (Brink 1992:26). Brink (1992:21) concludes: *It is no exaggeration to conclude that there are a variety of possible 'micro foundations'. Similarly, there are a variety of macroeconomic theories to be 'founded'…it is far from clear what is meant by a unification of micro and macroeconomics.*

as a characteristic of the real world that cannot be kept exogenous to the analysis. In this approach the normative criteria for evaluating value is the **continuity** of the systems under observation. Goudzwaard (1982:152-156) points out that such norms could also be described as a **survival** or systems norm, which is also a criterion of **adaptation** (Strijbos 1988:71).

The differences between the underlying question about what constitutes value, become clear in the debate on the valuation of the environment. The capital-theory approaches rely on welfare economic tools for valuation. Neoclassical environmental economists emphasise the change in consumer surplus while ecological economists emphasise the change in producer surplus as a welfare estimate. The neo-institutional approach emphasises the cost of changes in either consumer or producer surplus. The capital-theory approaches are therefore rooted in the controversies surrounding welfare economics in general. Evolutionary approaches tend to move beyond a static supply and demand framework to an analysis of the value of patterns of production and instrumental principles of social value.

The valuation of environmental change is done against the backdrop of the normative criteria of the different theoretical approaches to economics and the environment. The environmental economic and neo-institutional emphasis on efficiency fits well into the welfare-economic framework, while the ecological-economic emphasis on sustainability could fit in the welfare-economic framework if some boundary conditions for environmental degradation are defined. The focus of the evolutionary approach on survival would not require a valuation of environmental change in the first place, but a focus on adaptation to changing circumstances.

The valuation of the environment can be informative when changes need to be measured against their impacts on various interest groups. Although not discussed in this thesis, various techniques are available to derive economic values for the environment (Winpenny 1991; Georgiou *et al.* 1997). Environmental economics can provide valuable insights in the use values and some non-use values through contingent valuation techniques. Ecological economics plays an important role in placing a value on use and non-use values of ecosystem services by highlighting the importance of a changing producer surplus. Evolutionary economics provides a set of value principles acting as constraints on the patterns of development. However, these values do not represent a scientific objective truth-value, but are derived within the theoretical context of the normative criteria of respectively efficiency, sustainability or survival. Using the analogy of Heisenberg's **uncertainty-principle**, as introduced in section 1.2, the CTAs can give some good information on the substantivist approach to nature of the environment, but only at the expense of the direction and speed of environmental change. In turn, the evolutionary approaches can provide good information on the direction and speed of environmental change, but only at the expense of the structured nature of the environment. The balance between applying these values is a policy-making problem and one to be approached on a case-by-case basis.

3.4.2 Ethical and social limits

The normativist philosophy, as discussed in Chapter 2, and the negative outcomes of current economic systems might suggest that there are ethical and social limits on the interactions between the economy and the environment. This means that the use or pollution of the natural environment could be contained for reasons other than economic or ecological arguments. The rationale for ethical and social limits to growth is exemplified in the literature on ethics and economics (Sen 1970; Daly 1996) and the social effects of economic growth (Hirsch 1976; Mishan 1971).

For the purposes of this thesis the ethical dimensions of economic growth are summarised in two arguments:

- consumerism of current generations
- an erosion of moral standards due to a pursuance of self-interest

In the first dimension two concepts are included: current versus future generations and consumerism. The inclusion of the preferences of future generations is central to the debate on sustainable development, which will be developed further in Chapter 4. Some economists, working outside the parameters of the neoclassical economic framework, have argued for an ethical treatment of future generations' preferences outside the realm of traditional economics (Daly 1996; Howarth & Norgaard 1995). According to these lines, consumerism is often attacked, but normally with a very cautious conclusion on the prospects of changing people's behaviour (Galbraith 1995:61; Martinez-Alier 1995:57). On the other hand, economists working in the neoclassical tradition defend the autonomy of free choice. The main argument is that a substitution of individual responsibility for bureaucratic responsibility, often accompanying political and ethical norms, is an invitation to failure (Friedman 1995:63). This is also the position taken in environmental economic theory – changes to environmental responsibility have to be internalised in individual perceptions of utility. In response to such a position, others point out that history has shown us that human nature is very difficult to change. Experiments in both Russia and China have not changed human nature (Simon 1995:70). Ethical limits to economic growth may exist, but cannot be included in any policy-making approach without including a discussion on the character of political decision making and the sensitivity of individual behaviour to environmental changes.

The erosion of moral standards due to self-interest is interpreted by some as demonstrating the need for ethical limitations on economic growth. For instance, Goudzwaard and de Lange (1995) developed the **economics of enough**. The unlimited accumulation of capital, dictated in traditional economic theory as an increase in welfare, is perceived to be a fallacy. Welfare is measured against a higher set of norms, therefore individuals and organisations should be guided by normative principles when making choices, not by self-interest. This is an important critique on interpretations of economy-environment interactions, but one that will not be further discussed in this thesis.

The incomplete frameworks of the theories on economics and the environment suggest that externally defined ethical limits cannot be ignored. Such ethical debates should therefore be included in the development of economic policy approaches to sustainable development.

The social limits of economic growth have also received attention in recent years. Economic growth has not brought an equitable distribution of income or a clean and healthy environment. The expected high level of human happiness has not been achieved (at least not for all), instead, the self-cancelling effects of economic growth on welfare have been well documented in the literature (Daly 1996; Ayres 1995; Scitovsky 1976; Hirsch 1976). Money does not buy happiness and it does so at a decreasing rate, a situation often referred to as the **Easterlin paradox** (Easterlin 1974). Economic growth will not automatically lead to social happiness and equity, for the reasons spelt out in Table 3.4.

Table 3.4 The social limits to economic growth

Social limits to economic growth
▪ The inclination of economic growth to mass production and specialisation takes away pleasure in working (Scitovsky 1976). A recent addition is repetitive strain injury (RSI). An example of RSI is the **carpal tunnel syndrome** associated with working at computer keyboards (Ayres 1995:121).
▪ Economic growth needs space and starts competing with the intrinsic values of other species. The loss of species is a well-known phenomenon.
▪ In essence wealth is a question of relative wants. Growth does not lead to an absolute increase in welfare. It's only important to keep up with the Joneses (Hirsch 1976). Daly (1996:36) refers to this struggle for relative shares as a zero-sum game and compares it to the self-cancelling trap we find in the arms race.
▪ In countries where basic needs are still difficult to meet, economic growth is often seen as the mechanism to improve the situation. Economic growth does not lead to development per definition. Poverty, unemployment and inequality have frequently increased in the presence of high rates of economic growth (Todaro 1989:87).
▪ Despite economic growth, income inequality is still on the rise (Ayres 1995:124). A recent study of 56 countries found a strong negative relationship between income equality and economic growth (Persson & Tabellini 1994).

Sources: Quoted in the table.

3.4.3 Biophysical limits and the laws of thermodynamics

The natural environmental processes are not perpetual by definition, but are determined by the laws of thermodynamics. In the economic literature the aspects of environmental services to human beings are described by the **material balance principle** and the **entropy principle**. Ayres and Kneese (1969) provide the first onset towards the development of the material balance model with a discussion on material flowing from the environment to the economy and back. The model was developed in a subsequent paper (Kneese, Ayres & d'Arge 1970). This model is an application of the **first law of thermodynamics**, which states that the total amount of mass/energy is conserved in all processes, also in the transformation of materials. Energy is neither created nor destroyed (Smith 1996:169). This means that production and consumption must require some inputs of material and energy from the environment and generate some waste, a situation well described in the Coddington-model and in contributions from environmental & resource economics.

Although the total amount of energy does not increase or decrease the quality of the energy deteriorates over time. A measure of this increasing relative disorder is entropy. This is the subject of the **second law of thermodynamics**. This law states that entropy increases in any irreversible process. When entropy increases the amount of useful energy decreases. Boulding (1981:11) refers to this law as the **bathtub theorem** – a system that is steadily running down without replenishment. This second law is based on an isolated, **closed** system, in which there is no exchange of energy or matter between the system and its surroundings. A closed system tends to run down, an open system does not (Smith 1996:169). Thus, for making entropy a useful concept, the thermodynamic system **and the boundaries** of such a system have to be defined (Dyke 1994:210-212). The earth, however, is not a closed system as long as the sun shines, so in principle energy availability is not a problem. Therefore, even in the case of increasing entropy a stationary state can be achieved in the long run, if solar energy is used to its potential (Boulding 1966).

This thermodynamic vision implies that there are limits to the throughput of resources into production and consumption processes and back into the environment as pollution or waste (Georgescu-Roegen 1971; Daly 1996). This notion of ecological or biophysical limits has become a premise from which the largest cluster of work in ecological economics has been done (Costanza *et al.* 1997a:75). However, given the complexity of ecosystems the absolute levels of these limits are still uncertain.

The debate whether there are limits on economic growth illustrates the wide gap between economic and ecological approaches to the issue (for a discussion see Appendix A). However, without an appeal to values that are true by definition, neither side could make a convincing case for unfettered economic growth or limited economic growth. The arguments are as good as the **a priori** values they are evaluated on – whether economic efficiency, sustainability or survival. As concluded in Appendix A, the complexity of the debate suggests a case-by-case approach for different spatio-temporal scales.

3.4.4 Risk, uncertainty and irreversibility

A discussion on the treatment of the passing of time is fundamental to the theoretical perceptions on risk, uncertainty and irreversibility. The concept of time in economics has been treated in different ways. Faber and Proops (1990:62-65) identify six approaches to time in economic reasoning:

- Static time: events are assumed to occur at one point in time, i.e. time does not appear as a variable.
- Comparative static: states of the system at two discrete moments are compared.
- Reversible time: the future and the past are treated symmetrically.
- Risk – Irreversible Time 1: the future and the past are treated asymmetrically, past events are known and certain, future events are not known for certain, but can be associated with known objective or subjective probability distributions. In economic theory this kind of uncertainty is called **risk**.
- Uncertainty – Irreversible Time 2: the future may contain novelty that is definitely unknowable; some future events cannot be associated with probability distributions based on past knowledge. In economics this kind of uncertainty is called **uncertainty**.
- Teleological Sequence – Irreversible Time 3: economic activities have a particular fixed time order and are directed toward a definite end or **telos**. This end can only be reached with the passage of time, for example production activities. Economic processes have inertia, where the temporal length depends on the aim to be attained. In general, a shorter economic time horizon means that more events are irreversible, while a longer economic time horizon means that more events are reversible. Some processes are always irreversible, such as the combustion of coal or the extinction of species (Faber & Proops 1990:64). This is the concept of time as referred to in process economics.

Whether the changing realities through time are predictable or not, depends on the **type** of irreversibility. When time is treated as being reversible, it is by definition predictable. Unpredictable processes are those where novelty is emerging over time, thus including uncertainty and teleological sequence with an unknown telos (Faber & Proops 1990:73). The relationship between predictability and time irreversibility is illustrated in Table 3.5.

Table 3.5 Predictability and time irreversibility

Type of Irreversibility	Predictable	Unpredictable
Risk	√	√
Uncertainty	—	
Teleological Sequence (known telos)	√	—
Teleological Sequence (unknown telos)	—	√

Source: Adapted from Faber & Proops (1990:73).

This discussion on risk and irreversibility is important for an understanding of the limits and application potential of the various theories on economics and the environment. The substantivist CTAs tend to calculate the risk of future events, although the ecological-economic approach takes more cognisance of potential irreversibilities through the emphasis on biophysical limits. Both, however, attempt to include some level of prediction in their models. In the evolutionary approach the future is treated as uncertain and one where novelty is occurring all the time, excluding any serious attempt at prediction.

3.4.5 Process and time

Not only the concepts of risk and irreversibility are important when discussing the future, but also organisation and complexity. These concepts can best be explained by means of the two time lines (as borrowed from the natural sciences): The **First Arrow of Time** refers to the tendency over time of natural systems to disorder, also summarised in the second law of thermodynamics as discussed in section 3.4.2 (Georgescu-Roegen 1971; Faber & Proops 1990:62). However, the world is not only running down, but there is also growth, development, structuring and organisation (Faber & Proops 1990:76). This **Second Arrow of Time** reflects the tendency over time of certain systems towards greater organisation and complexity. These changes may be novel, for example technological progress and innovation (Faber & Proops 1990:85). According to Faber and Proops (1990:215), the sources of novelty in the interaction between the economy and the environment are, firstly, the invention of new techniques of production (nuclear power, micro-electronics), secondly, new types of interaction between economic activity and the global ecosystem, for example global warming, and thirdly, the alteration of social aims and norms.

These two Arrows of Time can be related to the different approaches to time in economics as defined in the previous section. The First Arrow of Time relates to a natural system changing from a present state to a future state which is not known with certainty, but about which certain statements can be made, e.g. increasing entropy. In this respect the First Arrow of Time reflects time irreversibility 1 or risk (as discussed in the previous section). The First Arrow of Time also has a teleological aspect, in that higher levels of system entropy can only be attained by first passing through lower levels of entropy, which involves both the passing of time and a certain direction (Faber & Proops 1990:77). There is no known **telos** in such natural processes, but it could still be treated as Irreversible Time 3 – teleological sequence with an unknown telos.

The Second Arrow of Time is novel and can therefore be said to reflect time irreversibility 2 or uncertainty (Faber & Proops 1990:78). In addition, complex systems emerge from simpler components, illustrating both the passage of time and a particular direction – irreversible time 3 with an unknown telos. In Table 3.6 the relationship between the Arrows of Time and types of time irreversibilities are illustrated.

Table 3.6 The Arrows of Time and time irreversibility

Types of Time Irreversibility	First Arrow	Second Arrow
Risk	√	—
Uncertainty	—	√
Teleological Sequence (unknown telos)	√	√

Source: Faber & Proops (1990:78).

This discussion is important for an understanding of the realities that are described by the different theories on the environment. The CTAs are limited to an interpretation of risk as associated with the First Arrow of Time[20]. Novelty, as occurring in both environmental degradation and innovations, can only be treated within the framework of an evolutionary approach.

3.4.6 Technology and innovation

It is often argued that technological developments will be able to circumvent any possible biophysical limits to economic expansion (Simon & Kahn 1984; see Jones & Hollier 1997). In the capital-theory approaches to economy-environment interactions technology is either expressed as a capital/labour ratio, or included explicitly in the production function (Mansfield 1988). Neoclassical economic theory includes the possibility of substitution of ecological services for technological developments. Ecological economics, however, adds the notion that substitutability is often not possible – technological developments will not be able to substitute for lost ecological services (Appendix A, section A.2.2.4). In such a case technology will at best be able to increase the efficiency in throughput, but it would not be able to mitigate entropy. Technological developments do also often lead towards biophysical limits instead of circumventing them (Colborn, Dumanoski & Myers 1997).

[20] See Aalbers (1999:68) for a discussion on probabilities in environmental-economic interactions.

Another aspect related to technology and innovation is the process of innovation itself, as brought forward by evolutionary approaches to economy-environment interactions. The source of new technologies lies in the processes of invention and innovation (Dugger 1984). This process cannot be explained through a narrow analysis of either socio-economic, technological or cultural conditions alone, or as a process of continual interaction (Dosi *et al.* 1988; Nelson & Winter 1982).

Schumpeter (1934) attempted to link innovations to business cycles. Schumpeter argued that important innovations would occur at the start of an upturn in the business cycle. The more wealth is increasing the less propensity there is to innovate. Although this theory signals a relation between economic and technological developments, it gives no explanation of the process itself.

Without discussing the process of technological development in detail, the point can be made that the CTAs to economy-environment interactions will be too limited to internalise the process of innovation in economic policy-making approaches to sustainable development. Within the CTA the differences between the environmental and ecological economic approaches also point to different policy-making approaches on the substitutability of technological developments for natural capital.

3.5 ECONOMIC APPROACHES TO POLICY MAKING: THE CASE OF GLOBAL CLIMATE CHANGE

3.5.1 Introduction

In the discussion up to now it has been suggested that various economic theories on the environment emphasise different aspects of reality, both on substance and process. The capital theory approaches emphasise economy-environment interactions through the building blocks of production, consumption and the environment, while the evolutionary approaches emphasise the dynamic nature of economy-environment interactions. An extended framework of the Coddington-model on economy-environment interactions has been presented so far. The next step would be to assess economic policy approaches to global climate change against this framework.

3.5.2 Economics of climate change: CBA approach or efficiency criterion

The literature on the subject categorises traditional responses to the problem of climate change in the cost-benefit analysis (CBA) framework and the sustainability framework (Pearce 1995:13; Bowers 1997; Pearce 1998:326-335). The CBA approach is founded in welfare economic theory. CBA analysis can be used to compare private, economic or social cost and benefits, largely depending on the objectives of the conducting agent. An extended CBA can also take account of distributional aspects, but this has not been applied in practice often (Squire & van der Tak 1975). The limitations of a cost-benefit analysis have been thoroughly reviewed in the literature (Pearce 1976; Joubert *et al.* 1997; van Pelt 1993). Increasing complexity in the estimation of benefits, i.e. monetary valuation of a change in environmental quality, has led to a broader family of decision techniques (Jepma & Munasinghe 1998). In a broader sense CBA analysis includes the cost-effectiveness approach (CEA), multi-criteria approach (MCA) and decision analysis (DA) (Jepma & Munasinghe 1998). The CEA approach is used when benefits are constant or are not available in a format that can be compared to the costs of a particular project or policy. The CEA reduces to finding the least-cost solution to meet a particular level of benefits. The MCA approach, like the CBA approach, is a trade-off between costs and benefits, but allows for less rigorous representation of the cost and benefits. To place an economic value on environmental damages is often problematic and multiple objectives are compared to a set of selection criteria. In DA the focus is on making decisions under uncertainty. This approach provides a systematic approach to solving complicated problems.

Making decisions about climate change involves determining the appropriate level of abatement and adaptation (Pearce 1998:326). To set these levels a framework for analysis is needed. Pearce (1995:14) distinguishes between two broad perspectives on the way benefits and costs should be compared, namely:

- judgemental CBA framework
- monetised CBA framework

In the first approach gains and losses are compared without reducing them to common units. One should think of either the CEA approach where benefits are not expressed in a common unit to the costs or a MCA approach where multiple objectives are not reduced to a common unit. In a monetised CBA framework, however, benefits and costs are reduced to the same monetary unit to permit direct comparison as far as this monetisation is credible. These benefits and costs are expressed in terms of human preferences. Future generations are included at least in so far as they are assumed to want what current generations want (Pearce 1995:14).

The CBA framework is a standard evaluation tool in the economic analysis on climate change (Nordhaus 1994; Cline 1992). While these models do not provide, or attempt to provide, a final answer on climate change, they do provide useful insights in understanding the economics of climate change (Tol 1996). The many underlying assumptions and simplifications, although necessary when modelling a very complex problem, have to be borne in mind when applying the results in the policy arena.

It is particularly difficult to assess cost and benefits of action on global climate change. In chapter 1 the added complexities of the climate change problem were listed: high scientific, economic and technological uncertainties, potential irreversibilities, non-linear causal chains, a very long timing horizon and the global scale of the problem with varying regional implications. These complexities reduce the confidence in monetary values as based on the CTA alone. It has been argued in section 3.3 that the CTA is not particularly useful when dealing with processes that are complex and cannot readily be reduced to probabilities of risk. If there are inherently unpredictable events these can only be described by evolutionary approaches to economy-environment interactions.

Ethical and social limits to economics are also problematic to include in CBA analysis. The distribution of costs and benefits, a key element of the social limits to economic growth, is a detrimental factor in policy making and one that has not received adequate attention in the CBA approach. Passing the CBA test is neither necessary, nor sufficient to predict that policy will be accepted in the political process. The reason is that the aggregated costs and benefits do not tell us anything about **who** enjoys the benefits or bears the costs (Bradford 1997:2). A CBA on climate change, whether correctly discounted or not, is unlikely to provide enough information for predicting or guiding choices. What needs to be added is information about the distribution of gains and losses over time and across space (Bradford 1997:9). However, despite these complications, a CBA is still very helpful in making decisions on even such complex issues such as global climate change (Bradford 1997:10).

The valuation of costs and benefits can become ambiguous when different valuation paradigms are used. It has been argued in section 3.4.1 that different theories on economy-environment interactions can have different fundamental principles of value that are rooted in the **a priori** normative criteria on which these theories are developed. This, however, is a complexity in every decision-making process, and the only recommendation would be to expose valuation paradigms explicitly in approaches to economic policy on climate change.

The CBA framework would have to include aspects of technological development and innovation to be aligned with the tendency of certain systems towards greater organisation and complexity. This is often difficult, if not impossible to achieve, as technology shifts are not always easy to predict. An evaluation of the evolutionary approach to the processes leading to innovation would be an option to include in economic approaches to policy of climate change. In this way the dynamics of technological developments over time would be better understood.

3.5.3 Sustainability framework

In the evaluation of the CBA approach to economic policy on climate change, nothing has been said about biophysical limits and the laws of thermodynamics. The second broad approach to economic policy on climate change, namely the sustainability framework, gives highest priority to the avoidance of unacceptable damages to future generations (Pearce 1995:15) and is discussed separately here. This issue is perceived by some to be especially relevant in the context of the problem of global climate change as highly probable. However, as pointed out by Pearce (1995:19), one should not lose sight of the potential loss of current generations and that a cautious approach to future damages involves some trade-offs for current and future generations.

Within the sustainability approach there are two dominant views (Pearce 1995:19):

- absolute standards approach
- safe minimum standards approach

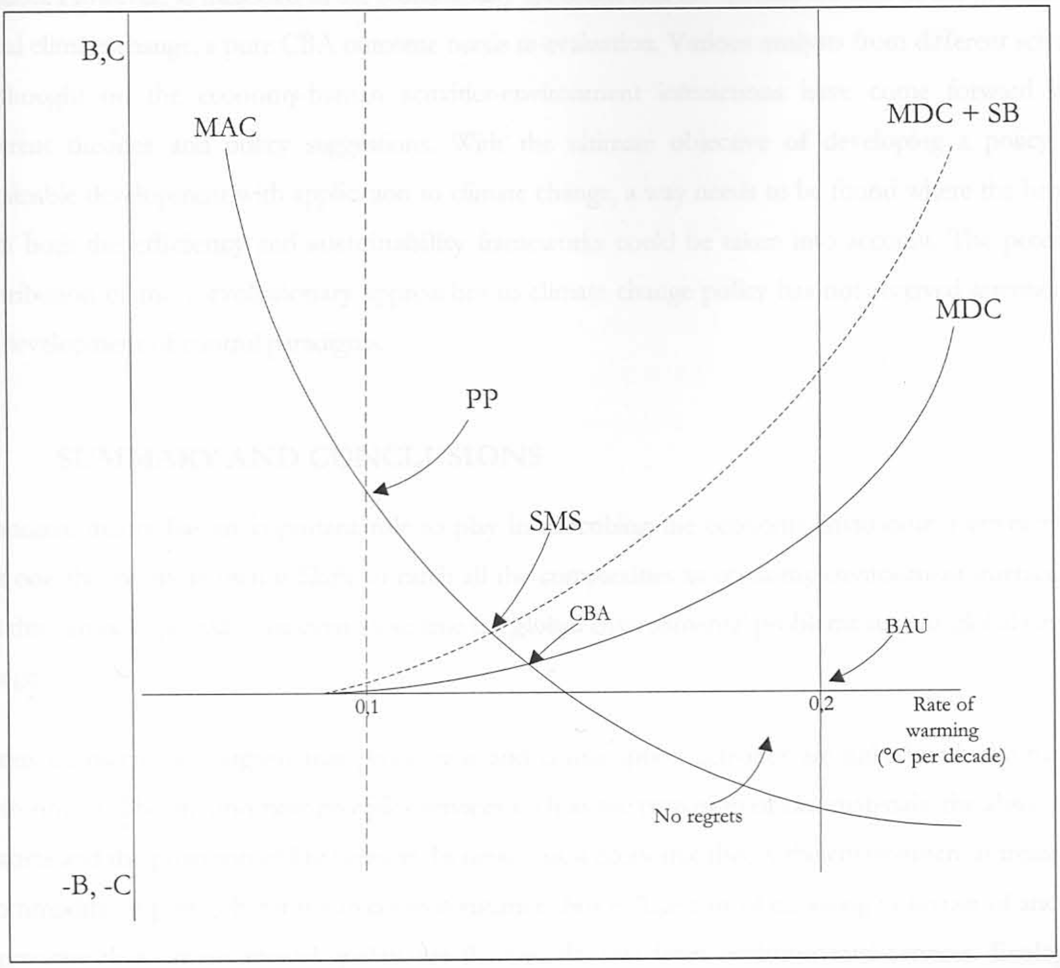
In the first approach the costs of damage control is irrelevant, it is perceived that the benefits of control, are so large that it is not even worth bothering about valuing these damages. In the second approach this position is watered down a bit by accepting the decision rule that damages should be avoided subject to the constraint that such avoidance does not itself impose an unacceptable cost. This approach aligns closely with the ecological economic notion of biophysical limits.

3.5.4 Economic policies for global warming: a comparison of control paradigms

Neither of these traditional responses to the problem of climate change is non-controversial. Where the CBA framework requires a monetary valuation of uncertain and possibly irreversible impacts of often non-linear ecosystem feedbacks, the sustainability framework fails to take into account the trade-offs that have to be made between objectives (of now and of the future). In addition, the substantivist framework of both these approaches are not including aspects brought forward by process economics.

The policy impacts of the different frameworks are shown in Figure 3.3.

Figure 3.3 Economic policies for global warming



Source: Pearce (1998).

The business-as-usual (BAU) scenario means to do nothing and hence continue to warm the earth by 0.2 °C per decade. A 'no-regrets' policy is aimed at using all abatement and adaptation measures that have a negative cost. The CBA framework determines an optimal outcome where the marginal abatement costs (MAC) and marginal damage costs (MDC) of the control of global warming is equal. For a correct representation the MAC should be equal to the MDC (including secondary benefits (SB)). The precautionary principle (PP) and the safe minimum standards (SMS) approach could in theory be the same if the opportunity costs of applying the SMS is not unacceptably high. The meaning of unacceptably high costs is indeterminate and the SMS is shown to be somewhere between the PP and CBA policy outcomes. The PP is identified with an avoidance of rates of warming in excess of a threshold, shown in Figure 3.3 as 0.1 °C. Figure 3.3 demonstrates the economic inefficiency of the PP, SMS and BAU approaches. No regret policies are an essential first step, but would not reach an economic efficiency where the MAC is equal to the MDC.

If **economic efficiency** were the only objective the CBA outcome would have been the ultimate policy solution. However, as indicated in the sustainability approach and the specific features of the problem of global climate change, a pure CBA outcome needs re-evaluation. Various analysts from different schools of thought on the economy-human activities-environment interactions have come forward with different theories and policy suggestions. With the ultimate objective of developing a policy for sustainable development with application to climate change, a way needs to be found where the benefit from both the **efficiency** and **sustainability** frameworks could be taken into account. The potential contribution of more **evolutionary** approaches to climate change policy has not received attention in the development of control paradigms.

3.6 SUMMARY AND CONCLUSIONS

Economic theory has an important role to play in describing the economy-environment interactions. Not one theory on its own is likely to catch all the complexities in economy-environment interactions and this can be expected to be even more true for **global** environmental problems such as global climate change.

In this chapter it was argued that production and consumption activities are linked with the natural environment. The environment provides services such as the provision of raw materials, the absorption of waste and the provision of life-support. In neoclassical economic theory the environment is treated as a commodity, implying that it is subject to consumer choice. The cost of choosing in favour of another commodity than environmental quality, are the benefits lost from environmental services. Ecological economists argue that choice is constrained by the biophysical (and socio-ethical) limits on production and consumption. Neo-institutional economists argue that choice is constrained by the structure (and costs) of property rights. These approaches are in fact extensions of the hard core in neoclassical economics, the **capital theory** approaches.

Some analysts in the ecological economic school, and especially those working in the tradition of the (co)-evolutionary economic school, argue for a shift away from optimisation of an objective function subject to a set of constraints, to describing the changing realities or patterns of development (Faber & Proops 1990; Norgaard 1988). Most work in the evolutionary approach has focused on technological progress, invention and innovation, but some work has been done in the inclusion of biophysical limits over time. The fundamental principle of value is one of survival in a future full of novel events.

The economic analysis on the problem of global climate change has followed the broad debate within economic theories on the environment, but only within the framework of the capital-theory approaches. Both environmental economic and ecological economic approaches have been applied in respectively the CBA and sustainability rules for climate change policy making. The current debate on climate change policy is too focused on the substantivist approaches of capital-theory and could possibly be improved by including aspects of the processist view of changing realities.

This chapter ends with the question how to approach economic policy for sustainable development in the case of complex, dynamic problems such as global climate change. In this chapter it was argued that the economic policy framework has to include at least both aspects of the CTA and evolutionary approaches to economy-environment interactions. In recent years it has been argued that the concept of sustainable development should be the ultimate objective of human activities and not economic growth per se. The next question is whether the theories on sustainable development would provide an integrative framework for approaching economic policy to sustainable development with the inclusion of both CTA and evolutionary approaches to economy-environment interactions.