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Understanding Industrial Transformation:

Views from Different Disciplines

Edited by
Xander Olsthoorn and Anna J. Wieczorek

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Views from Different Disciplines

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Understanding Industrial Transformation

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‘A system is just like truth’s tail, but the truth is like a lizard. It will leave the tail in your hand and escape; it knows that it will soon grow another tail’

(Ivan Sergeevich Turgenev (1818–1883), Letter, January 3, 1857, to Count Lev Nikolaevich Tolstoy. Turgenev: Letters, ed. David Lowe (1983)).

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PREFACE

'It is increasingly recognised that important changes in production and consumption systems will be required to meet the needs and aspirations of a growing world population while using environmental resources in a sustainable manner. Scientific research that informs how to bring about system changes must overcome disciplinary boundaries and be international in scope. In recent years this challenge has been discussed internationally under the label *Industrial Transformation* (IT).'(IT Science Plan, Vellinga and Herb 1999).

This volume attempts to bridge disciplinary barriers by discussing a variety of social science perspectives on society-environment interactions, the driving forces of change and development trajectories that have a significantly smaller burden on the environment. The book shows how the unique perspectives of each of the disciplines may contribute to understanding and the design of possible solutions. This book is a reaction to the well-known observation that scientists often talk past each other and find it hard to establish common ground. This book illustrates the foundations of the different perspectives, aiming at a richer interaction between them. Disciplinary foundations are essential in the development of knowledge, but they need not be fixed and unbending. This book will have succeeded if it prompts readers to reframe some of their starting assumptions so that interesting new research questions can emerge.

The role of the Industrial Transformation programme of IHDP has been to bring together multiple approaches and to encourage discussion in the international and multidisciplinary fora. The IT and other IHDP programmes have been successful in helping to set agendas that stretch across disciplinary boundaries. Given the scale, depth and complexity of interactions between societies and natural environments, researchers face the continuing challenge of taking the broad view and of moving beyond the constraints of conventional disciplinary boundaries.

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Chair, Industrial Transformation of IHDP

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Chapter 1

INTRODUCTION

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Abstract: This Chapter introduces industrial transformation as a specific field of science. The key assumption of research on industrial transformation is that deep societal change is required to achieve sustainability. Its study requires concerted efforts from many scientific disciplines.

Key words: industrial transformation, International Human Dimensions Programme, global environmental change

1. WHAT IS INDUSTRIAL TRANSFORMATION?

A brief history

Up to the 1960s, post-war economic growth was considered a great achievement of industrial societies, as it secured social stability and welfare. After 1960, however, gloomier views of economic growth emerged as well, in particular with respect to its adverse environmental implications: increasing pollution, over-exploitation of renewable resources and depletion of non-renewable resources. Publications that mark the start of broad scientific interest in these issues include Ayres (1978), Boulding (1966), Hardin (1968), Daly (1977), Ehrlich *et al*. (1977) and Georcescu-Roegen (1971). In the beginning of the 1970s, the publication of the *Report to the Club of Rome* (Meadows 1972), which coincided with the oil crisis, led to a

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wide public discussion about the apparently catastrophic effects of continuous exponential economic growth.

Concerns about the adverse environmental impacts of economic growth were at odds with claims that economic growth would benefit the environment, the assumption being that environmental quality is a luxury good and people are willing to spend more on this good the richer they become (de Bruijn, 1999). The public debate on environmental policy-making, economic growth and the environment motivated research in these fields. In the beginning of the 1990s, the first results (*e.g.* Grossman *et al.,* 1991) of empirical research on the relation between wealth and environmental quality pointed to an inverted U-shaped relationship between income and emissions of certain pollutants. Panayotou (1993) suggested naming this relationship the Environmental Kuznets Curve (EKC), after the similarly-shaped relation between income inequality and per capita income, established by the economist Simon Kuznets (Kuznets, 1955).

Of course, the EKC is just a simple statistical relationship. But the EKC implicitly suggests that existing governance structures and technologies will suffice in addressing environmental problems. That is, existing economic signals and political institutions can handle the problem without *deep* societal change, as long as there is sufficient economic growth.

This notion may have facilitated mainstream policy institutions, such as the World Bank (1992), to take policy initiatives that specifically aim at de-linking economic growth from its environmental burdens. In May 2001, the decoupling of environmental pressures from economic growth became one of the main objectives of the OECD Environmental Strategy for the First Decade of the 21st century (OECD, 2002). The EKC may also have been instrumental in the OECD countries' committing themselves — at the Rio Earth Summit in 1992 — to sustainable development (Brundlandt, 1987), which says *inter alia* that environmental improvement goes hand in hand with economic (and social) development.

However, in spite of some undoubtedly successful environmental policy and '…despite all the elegant rhetoric that surrounds discussions about sustainable development, we are far from having made significant progress toward that goal.' (Johnson 2002, 26) Research on past trends and on the prospects for future decoupling indicates that there has been only *certain* decoupling of *some* emissions in *selected* developed countries (Azar *et al.*, 2002). Relative decoupling (emissions of pollution per Euro of GDP) is commonly observed, but there is much less evidence of absolute decoupling (total emissions to the environment). Some environmental problems appear to defy the downward trajectory of the EKC. Emissions of greenhouse gases, for instance, have continued to grow in many countries, despite the development of climate mitigation policies. Likewise, in the fast-growing developing countries and in cities, emissions and problems linked to key resources, such as water, are on the rise. Even with relative decoupling, by adopting solutions applied in developed countries, growing populations are a decisive factor for the growth of these problems. Some sectors, notably transport and food production, appear to be especially insensitive to efforts to improve their environmental performance.

The irreversibility and persistency of problems associated with resource use and environmental services call for another category of actions beyond those suggested by the EKC. In particular, longer-term and more fundamental changes appear to be needed. What kinds of system change we need to consider, and how to evaluate their effectiveness has been the overarching policy question posed by the International Human Dimensions Programme (IHDP) on Global Environmental Change (GEC).

The IHDP programme

IHDP was brought into existence in 1990 by International Council for Social Unions (ICSU) and International Social Science Council (ISSC) to complement the ongoing natural scientific research on Global Environmental Change coordinated largely by two older GEC programmes: International Geosphere Biosphere Programme (IGBP) and World Climate Research Programme (WCRP). Although its name may suggest otherwise, IHDP's role was not to conduct purely social scientific research. Its aim was to build bridges over the many disciplines that contribute to a better understanding of the complex human-environment relationships and the predicaments of global change.[2] The IHDP has been created as an international, interdisciplinary and non-governmental research programme, aiming at '…the development and integration of research on the human dimensions of global environmental change'.

IHDP stems from *(i)* the observation that the global environment is changing, (*ii)* the analysis that human activities account for the larger part of this change, and (*iii)* the belief that, without intervention, the current pattern of human activities is having and will eventually have severe adverse effects on global environmental systems. The research mission is to analyse the 'pattern of human activities' in order to identify leverages for reducing the environmental risks.

2 Since 2001, the three programmes (IHDP, IGBP, WCRP), as well as a fourth, Diversitas (looking into the biodiversity aspects of GEC), have formed the Earth System Science Partnership (ESSP). The goal of the ESSP is to develop that type of integrative science that is necessary for understanding the Earth System and its stewardship.

Industrial Transformation (IT)[3] is one of the core science projects of IHDP. Within IT research (Vellinga and Herb, 1999) two major observations were made. The first relates to the phenomenon of 'lock-in' of technologies. Lock-in refers to the situation that the use of a certain technology — for example, the petrol-fuelled car — is embedded in a wider pattern of human activities, each involving other technologies and institutions, such as the system of petrol supply. The successful introduction of mass hydrogen-fuelled cars depends on the emergence of an alternative system to supply hydrogen for these vehicles. The thrust of the concept of lock-in is that the introduction of a certain environmentally-desirable technology requires 'side' policies.

The second observation is about the economics of technological change (Verbruggen and Kuik, 1999). Economists have long been concerned with the concept of the incentive structure: such a structure (and its history) would explain the current techno-economic system. For instance, since the cost of environmental damage caused by car pollution is not borne by the car owner — the polluter does not pay — there is no economic incentive for producers, in the form of market demand from consumers, to produce low-emission cars. In such cases, a way out is for government to set regulations, such as emission standards that with which car makers and drivers must comply.

The analysis of the IT programme starts with the notion that changes in technologies — put differently, changes in the ways in which humans use environmental resources and services — are embedded in changes in the social realm. While many agree about the desirability of having cleaner technologies, their introduction and use is influenced by social and economic factors. According to industrial transformation research, to combine growing income levels with significant reductions of human impacts on global life support systems, deep changes in the structure of current economies and societies are likely to be necessary. In other words, system changes are required that go beyond the domain of individual sectors, but include chains of production and consumption, including distribution and disposal activities. System changes encompass the incentives that shape this system (*i.e.* property, liability and fiscal laws and regulations). System changes affect and involve social actors (government, producers, and consumers), the flow of goods and/or services (including industrial 'metabolisms'), and the overall physical and institutional settings in which they operate. Given system complexity, and given the need for a purposive approach, such

[3] As a clarification, in this book we have used the term *industrial transformation* in its non-abbreviated form to describe the *process* of industrial transformation. The abbreviation, IT, is reserved for reference to the IT programme of the IHDP.

system changes call for the involvement of society as a whole and an inspiring vision to mobilise and coordinate social action.

About the concept of industrial transformation

We have observed some confusion about the industrial transformation concept, mostly with respect to the adjective *industrial*. We relate this misunderstanding to the fact that in some languages (*e.g.* in Dutch and in German) the term 'industrie' refers solely to manufacturing industries, while in English the meaning of 'industrial' is not restricted to materials-processing activities. In English, *industrial* refers to any human activity that, through systematic labour, produces goods or services. In *industrial transformation,* 'industrial' has the latter connotation. So, for instance, agriculture and tourism are sectors that are within the scope of the IT programme.

A second confusion might arise from the non-discriminatory use of the terms *transformation* and *transition*. We consulted main reference dictionaries in an attempt to sort out whether these terms are divergent. The explanations in the dictionaries suggest that *transition* comes from the Latin verb for 'to pass through,' and refers rather to the process of change, while *transformation* refers to both the process, as well as to the beginning and the end states (forms) of a process or development like, *e.g.* the pupation of a caterpillar to butterfly, or the change of a pre-modern society into a modern society. We also found that native English speakers tend to take *transition* as less important and having a lower pace than *transformation*. Changing form seems therefore more fundamental than simply passing through. It is indeed changing form in which industrial transformation is interested.

Another confusion arises from *industrial transformation* is assumed to refer to the industrialisation process — a change of pre-modern society into modern society, with the advent of fossil fuel-based manufacturing industry and the creation of the class of industrial labourers that occurred in Europe in the nineteenth century. In sociology, however, one refers to this process as *industrialisation*.

This leads us to a clarification or justification of the term industrial transformation. If we consider all human activities, then why not use *societal transformation*? This is since, conceptually, we focus only those activities that raise concerns because of their environmental implications. Thus, *industrial transformation* is a subset of societal transformation. By using this name for one of the IHDP projects, the originators wanted to emphasise that a sustainable future implies more than change in a technological sense only.

The relevance of research on industrial transformation

The main question that confronts researchers of industrial transformation is: ‘what policies can be pursued to avoid futures that are unsustainable?’ This question will be raised by decision makers from different governance domains: not only by national and international governments, but also by firms and NGOs.

The policy domain — the set of levers for policy making — is composed of activities that connect with sustainability, in particular those aspects that promote processes of change towards sustainability. Environmental policy is one of the main areas to which industrial transformation research is relevant; other areas might include economic policy, energy policy, agricultural policy, consumer policies and urban policies. There is no geographical boundary to the policies that IT wants to support and advocate. Since, however, many of the environmental problems dealt with in IT research have their origin in developed countries, the most relevant policies address issues in these societies.

What do policy- and decision-makers need from science? Usefulness may refer to the clarification of policy problems and claims. Sound science helps. Scientific value refers to an agreement among trusted/peer scientists about the relevance of the outcomes of research for the design of an action to meet a policy objective. An objective may range from producing a drug for curing some disease, producing a safer car, or reducing unemployment, to improving air quality or reducing dependence on fossil energy resources. Scientific relevance refers to qualities such as internal consistency and clarity about the scope of conclusions. High scientific value does not necessarily lead to high usefulness for policy-making, for various reasons. For instance: it might be irrelevant if the scope of its conclusions do not relate to the framework of policy issues that decision-makers are concerned with. A study that concludes that the widespread use of hydrogen as a fuel is environmentally-beneficial, without indicating the economic consequences, may be accepted as scientifically-sound, but have little operational relevance to policy-makers, except for raising the policy question about the economics of hydrogen fuel use.

From the viewpoint of the policy-maker there is a question of the relative usefulness of the products of industrial transformation research. Policy-makers want adequate descriptions of policy goals and recommendations on the right instruments. Scientists could give answers, but it is seldom the case that they accurately understand how stakeholders perceive the issue. This problem is especially acute in relation to sustainability issues, where deep disputes may exist about the relative importance of different issues. The role of scientists is therefore limited to helping, by providing sound science, while the role of decision-makers and stakeholders may be to sort out policy issues and agree on actions.

2. ABOUT THIS BOOK

Since the publication of the IT Science Plan in 2000, several research projects have been initiated and/or endorsed by the IT programme around the world. In addition, the IT office has created a database of research considered to be relevant to the industrial transformation domain. Conferences and workshops have been organised to discuss research on broad environmentally-driven innovations towards sustainability.

Characteristic of industrial transformation research is that: *(i)* industrial transformation research requires the integration of knowledges (scientific and practical) that are typically shared between person and teams, *(ii)* industrial transformation research often requires non-sectoral approaches to problems, if for no other reason than that the industrial sectors are linked in complex ways, and *(iii)* industrial transformation research is inherently international, primarily because the flow of raw materials and processed goods is global.

This book aims to contribute to the development of industrial transformation research in particular with respect to the first criterion. We think this is important since our impression from the work so far is that there is room for a wider, cross-disciplinary integration in industrial transformation research. Our assumption is that there is scope for better coordination between disciplines.

The choice to use 'science discipline' as the headline principle to structure this volume follows from this proposition. This also allows an analysis of the extent to which disciplinary research is mutually-consistent and complementary. In the end, we hope to inform public policy-making with useful insights.

We admit that the selection of disciplines has not been an easy task. The first simple barrier we came across at the start was the issue of what *is* a scientific discipline and what *is not*, and which of the fields should be selected for analysis and which passed-over. In our search we discovered that there is no official, commonly-recognised categorisation of disciplines, since new disciplines are continually emerging through processes of specialisation and fusion. The disciplinary approaches presented in this book were narrowed using three criteria: applicability of a specific discipline to analysing industrial transformation; the availability of authors; and the available space in the book. We also wanted to avoid an overlap with an IT-endorsed edited volume '*System Innovation and the Transition to*

Sustainability' (Elzen, *et al.*, 2004) for a view on industrial transformation from the area of innovation studies.

We did not, however, fully comply with our 'disciplinary' principle. The Chapter by Frank Geels is a typical example of a multidisciplinary view on industrial transformation. We thought this view to be important since, besides its intrinsic merits, it is a prelude to the description of the framework for 'transition management' as adopted by the Dutch Government in its 4th National Environmental Programme (VROM, 2001). This policy might be seen as one of the first efforts to apply the ideas of industrial transformation in policy frameworks.

The book is built around nine chapters. The first seven can be classified as contributions from traditional disciplines: psychology; sociology; economics; political science; and law. Due to significant developments in the Netherlands we made some space — two chapters — for a description of the multi-level perspective on system innovation (the chapter by Geels) and transition management (the chapter by Loorbach and Rotmans). The concluding chapter is our attempt to summarise the various approaches and to seek the synergies between disciplines in the field of industrial transformation.

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[4] Prof. Dr. Ken Green, Manchester School Management, UK; Prof. Dr. Marina Fischer-Kowalski, Institute for Interdisciplinary Studies of Austrian Universities, Austria; Dr. Leena Srivastava, TERI, India; Dr. Nina Poussenkova, Russian Academy of Sciences, Russia; Prof. Dr. David Angel, Clark University, USA; Prof. Dr. Christian Azar, Chalmers University of Technology, Sweden; Prof. Dr. Frans Berkhout, SPRU, Sussex University, UK; Prof. Dr. Jose Moreira, CENBIO, National Reference Center on Biomass, Brazil; Prof. Dr. Pier Vellinga, Vrije Universiteit Amsterdam, the Netherlands.

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Chapter 2

A PSYCHOLOGICAL VIEW ON INDUSTRIAL TRANSFORMATION AND BEHAVIOUR

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Abstract: This paper argues that psychologists are only beginning to understand how global environmental issues may be related to the ways people create a ‘fit’ between themselves and their environment in order to survive. The notion of a person-environment fit is an analogue at the personal level of the concept of sustainable development at the level of society. Using knowledge from a wide range of behavioural disciplines (*i.e.* psychology, sociology, anthropology, history) the author presents a cascade-like framework that sorts influences on a person’s behaviour into a logical order. The framework combines perceptual and rational processes internal to the person with social, organisational, and distal processes (*i.e.* long-term causes). Two psychological processes are discussed in greater detail to highlight the role of personal values and the process of becoming mindful of changes in the environment.

Key words: distal and proximal causes, values, awareness, person-environment fit, behaviour

1. INTRODUCTION

What is a transformation from a psychological point of view? When psychologists say that someone has undergone a personal transformation, they mean that he or she has changed in more than one way. For example, the transformation from being a smoker into being a non-smoker is not just a

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matter of putting out a cigarette. The transformation involves all the changes that are connected with being a smoker, such as specific acts, beliefs and feelings about one's identity as a smoker and commitments to the world of smokers, including the tobacco companies. The person who quits the habit has to replace these elements with other acts, another identity and new commitments to the world of non-smokers. In sum, a transformation is more than just a change in a person's behaviour — it is a set of related changes. Although some of the changes may be planned, others have to be learned in the process of changing.

The transformations this paper aims to discuss are more than personal transformations, because they refer to potential changes at the level of society, such as a significant shift in diet from animal proteins to plant proteins. Psychologically speaking, such changes to a more sustainable diet are heavily dependent on consumer behaviour, although the behavioural change may not always be so personally involving as the case of smoking suggests. Moreover, a transformation at the level of society may also be dependent on workers' acceptance of a new technology and citizens' political choices. It is the relationship between industrial transformation and these types of behaviour (*i.e.* consuming, evaluating, voting) that this paper will focus on.

Given the breadth of industrial transformation, it is necessary to choose a broad behavioural approach that goes beyond studies into specific environmentally related behaviours, such as recycling (*e.g.*, Diekmann and Preisendörfer, 2003; Tanner, Wolfing and Kast, 2003). Another important consideration is that it was only two decades ago that experts started to think about global environmental issues, and the concept of sustainable development was introduced. Many people in Western countries spent their formative years in a period of increasing affluence and consumerism. Therefore, a broad behavioural approach should start with a closer look at the relationship between people and their environment, and put this relationship in the perspective of changes that occurred during people's lifetimes and beyond. Such an approach may help to clarify the most important messages that psychologists have for other scientists in this field.

One of those messages is that human behaviour is a very flexible phenomenon and that each particular manifestation of it can be the result of many determinants. The notion that human behaviour is flexible becomes particularly clear when we take an evolutionary perspective. Complex behaviour is a relatively new phenomenon that is closely connected with evolution (Cziko, 2000). The behavioural patterns of the early species were rather fixed and predictable (*e.g.* plants grow towards the source of light) but the patterns of later, more complex species have become far more varied and flexible (*e.g.* animals living in groups). As a result of being particularly flexible, groups of humans have been able to adapt to very divergent environmental conditions, varying from snow-covered hunting grounds to so-called High Reliability Organisations, such as space shuttles (Weick *et al.*, 1999; Whiteman and Cooper, 2000). In their respective settings, the hunter and the astronaut show extremely different behaviour, but they must both maintain a proper 'fit' between themselves and their environment in order to survive.

The notion of a person-environment 'fit' refers to a balance between, on the one hand, a person's values, capabilities and perceptions, and, on the other hand, the opportunities and demands of his or her environment. This personal 'fit' is analogous to the concept of sustainable development at the level of society. Particularly relevant here is that even though people may be more concerned about a 'livable' street (Appleyard, 1981) than about a 'livable' planet, they are not indifferent towards the way in which their welfare is generated (Bramwell, 1989). The initially successful storyline of a 'global nature' under threat and in need of protection from a global imagined community, however, has lost its appeal among the citizens of Western countries (Macnaghten, 2003). In their eyes, such a storyline is too simplistic.

In view of people's scepticism about the motives of those who propose simple solutions, it becomes increasingly important to obtain more insight into how global environmental issues may be related to the person-environment fit. Two psychological processes are particularly relevant in this context. The first involves the values that people internalise when growing up in a particular community (Schwartz, 1992). For example, a person who has learned to feel respect for the natural forces and hazards to which he or she is subject will feel rather uncomfortable in a setting where nature is being destroyed. The second process refers to people's awareness of changes in their environment (Langer, 1989). The examples of the hunter and the astronaut mentioned above show that both of them must be extremely mindful of unexpected changes in their environment. Alternatively, in a more relaxed context, people may find pleasure and satisfaction in being mindful of a good fit with their environment.

In the next section, I discuss the various determinants of behaviour by presenting a cascade-like framework that sorts them into a logical order. Then, I briefly examine the role of values and the process of becoming mindful of changes in the environment. In the final part of the paper, I shall explain that any behaviour-related intervention to support industrial transformation can only be successful if it contributes to a better person-environment fit.

2. ON THE CAUSES OF BEHAVIOUR

In considering the causes of a person's behaviour, it is important to take into account that any act is the result of multiple determinants. These determinants can be sorted into a logical order on the basis of two general notions. The first one is that it makes sense to consider, from a behavioural perspective, the time it takes to create or develop certain actions and phenomena. For example, a genuine problem cannot be solved in one second and a friendship cannot be built in an hour. These time limits say something about the underlying processes. The second notion is that any causal factor can only take hold in a certain context. In other words, a virus can only cause an illness among those persons who are not immune to it. The context, in turn, is also dependent on other causal factors, such as vulnerability to the virus as determined by heredity.

Apart from strictly biological phenomena, the most obvious determinants of behaviour are the perceptual and rational processes that enable a person to adapt his or her activities to the situation at hand. These adaptive processes refer, for example, to the taste of a food and the person's ideas about its origin. If a person is in doubt about the quality of a food served by a host, his or her behaviour may be influenced by personal loyalties to this host. Also relevant might be the person's thoughts about the business practices that are common in the food supply chain. In short, the behaviour in question is not only a function of processes within the person, but also of social and organisational processes that act as 'proximal' causes of behaviour.

Moving from processes that are internal and proximal (*i.e.* short-term causes) to more distal processes (*i.e.* long-term causes), we can see determinants of behaviour that will not dramatically change during the lifetime of an individual. These relatively stable processes can influence the person tasting the food, if, for example, he or she is drawn to beliefs about purity and danger that result from broadly shared worldviews (*e.g.*, philosophies of life, beliefs about magical powers). These worldviews have gradually changed over the past millennium, due to a process of cultural modernisation (Levine, 2001). Unlike mediaeval men and women, modern people will not expect solutions from magical powers but they may still be sensitive to some of these beliefs under conditions of uncertainty.

A final category involves evolutionary processes, which have shaped human capabilities to cope with the environment, for example the ability to make a quick distinction between sweet (*i.e.* rich in calories) and bitter tasting (*i.e.* possibly poisonous) foods.

The processes mentioned above can be arranged in the cascade-like framework shown in Figure 1. The framework is relatively new, although similar ideas have been put forward by others (Diamond, 1999; Newell, 1990; Oyserman *et al.*, 2002). The highest level refers to evolution of life. One of the results of evolution is that humans are able to distinguish between positive and negative stimuli in about 100 milliseconds (Smith *et al.*, 2003). Another relevant feature with an evolutionary origin involves the response strength of brain systems. The brain systems responsible for evaluating negative stimuli respond more strongly than those responsible for evaluating positive stimuli (Smith *et al.*, 2003). This so-called negativity bias means that negative stimuli (*e.g.* a suspect bitter taste) have a greater impact on information processing than do positive stimuli.

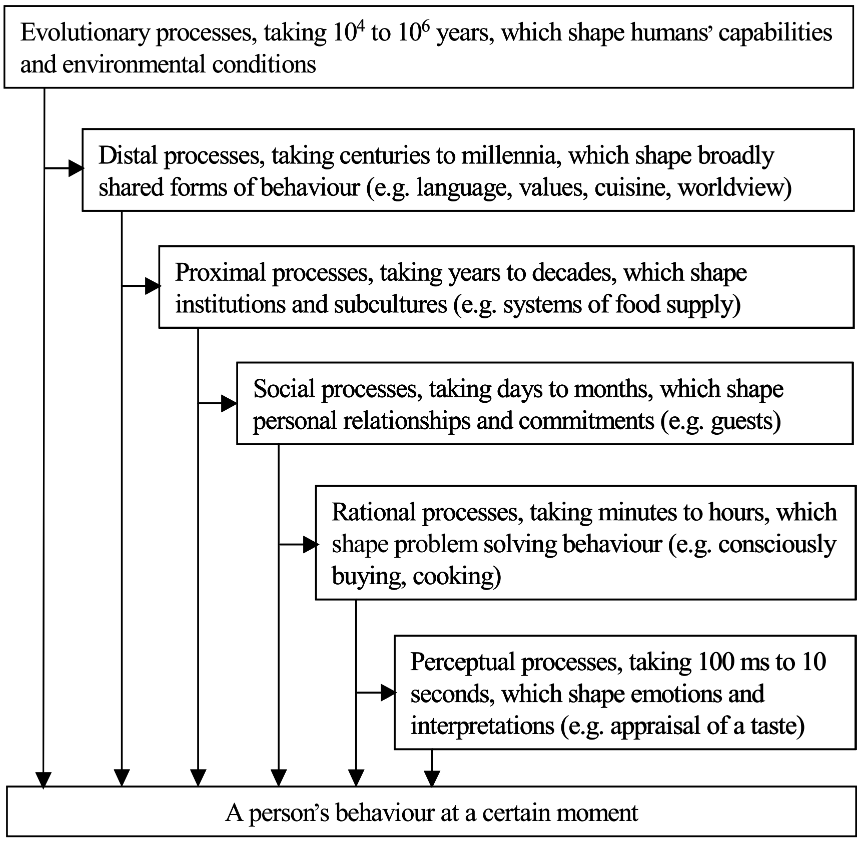

Figure 1. A cascade-like framework of influences on behaviour

The next level of Figure 1 refers to distal processes that have shaped broadly shared forms of behaviour over centuries or millennia. These include the rise of practices, values and worldviews that are typical of modern culture in the Western world. Put simply, the 'modern' period started in 1900 and modern Western societies can be distinguished from their predecessors by their potential to democratise both wealth and political processes (Levine, 2001: 11). The overall concept of modernisation covers a number of more specific processes, such as the growing importance of an 'engineering culture' characterised by the systemic application of scientific knowledge to societal issues (Carroll-Burke, 2001). This engineering culture produced the steam engine and many other things that account for the present welfare.

By their very nature, distal processes like modernisation have created both opportunities and constraints for the development of institutions and subcultures that belong to the proximal processes of Figure 1. These processes include the development of food supply chains and professional cooking that are heavily dependent on occupational cultures. According to Schein (1992: 12), such a culture may be seen as a pattern of shared basic assumptions that a given group (or organisation) has learned as it solved problems of external adaptation and internal integration. This is in agreement with the more general notion of culture as a set of coordinated practices that creates incentives and disincentives for the behaviour of the people involved.

The social processes in Figure 1 are more personal than the professional activities mentioned above, and take much less time to develop. For example, a person's loyalty to a colleague may grow in a few days or months. According to Newell (1990: 494), it is characteristic of social situations that there are multiple, somewhat independent goals present at all times. In a task-oriented group, for example, each person cares (*i*) about the task the group is performing, (*ii*) about maintaining the social atmosphere of the group, and (*iii*) about his or her own position in the group and the personal satisfactions of group membership. Regarding each of these goals, the person has an impact on the outcomes but he or she is also dependent on the other group members.

The processes mentioned above are external to the person, except for the social processes, which are a mixture of external and internal elements. The lowest levels of Figure 1 refer to processes that are internal to the person. The rational processes, often taking minutes to hours, include conceptual learning, problem solving and decision-making. Notably, Figure 1 shows that a person's behaviour is not fully determined by rational processes. For example, even if a person aims to take a decision in a purely rational way, he or she will soon find that social commitments and perceptual biases can interfere with such an approach as soon as the decision's consequences become serious.

Perceptual processes shape a person's rapid interpretations of situations and his or her subsequent emotional experiences. An important distinction at this level is that between mindless and mindful processing. Psychological research has shown that people who are generally capable of acting mindfully can actually perform seemingly complex tasks with little if any active mental involvement (Langer, 1989). This means, among other things, that they rely on routines developed in the past and that they do not make new distinctions to accommodate any changes of the task environment. In contrast, mindfulness is essentially an awareness of contexts. Without this awareness, a person cannot improve his or her performance, self-esteem or health (Langer, 1989). I will come back to this point later.

One of the notions behind the framework of Figure 1 is that the more distal factors provide the context in which the more proximal or internal factors can have their effect. This notion is particularly relevant for the impact of culture on behaviour. For example, the process of modernisation has enabled modern people to understand that disasters, such as floods, are not the result of magical forces, but of natural phenomena that can be analysed in terms of causes and effects. Under these circumstances, people have become more receptive to science-based advice on sustainable development, although they have also learned that modern scientists have their own interests in certain issues (Giddens, 1991; Macnaghten, 2003).

An important practical message of Figure 1 is that it is not necessary (if feasible) to change a culture completely in order to change a particular behaviour. The example of smoking shows how this might work. During the years 1910–1919, the American tobacco companies could rapidly increase the number of male smokers by using strong appeals to the culture of the American male (*e.g.* the Camel campaign); in later years, they also developed special campaigns for women (Pierce and Gilpin, 1995). Since the mid-1960s, however, other dimensions of this same American culture have been used in attempts by the social/health movement to ban smoking. New evidence revealed in 1986 that smoking was also life threatening for the people who shared the smoker's environment, contributed to the successful moralisation of smoking as behaviour that is unhealthy to others (Katz, 1997). In sum, the number of smokers could first go up and then go down without dramatic changes in the core values of the people involved.

The rise and fall of smoking demonstrates that the achievement of specific policy objectives (*e.g.* selling cigarettes or promoting health) can be aided or hampered by appeals to well-chosen values within the broader culture. These appeals have also been effective in the workplace, where people are or are not allowed to smoke. Prohibitive rules and disapproval by colleagues have finally inhibited the behaviour of potential smokers. This example shows that the impacts of an organisational culture and the social relationships at work might to a certain degree be in accordance with the broader culture. Such congruence between various causes of behaviour, however, cannot always be expected.

The lower level processes of Figure 1 are building blocks for the higher ones. For example, a non-smoking policy in the workplace will not succeed if an employee can mindlessly light up a cigarette without any negative feedback (*i.e.* level of perceptual processes). The policy will also fail if the employee consciously tries to evade the rules (*i.e.* level of rational processes) or strives to transform the rules by organizing protest meetings (*i.e.* level of social processes). The notion of building blocks does not mean, however, that an individual can fully understand how his or her behaviour contributes to social relationships, organisational cultures and long-term cultural changes.

The framework can help to diagnose the options for a behavioural change. First of all, it is important to gain insight into the congruence of the various influences on behaviour. The example of smoking shows that the effectiveness of interventions will increase if all the influences on a particular behaviour point in the same direction. The framework also helps in considering the role of time in diagnoses and interventions. The fact that the various influences on behaviour have their own pace has consequences for the diagnosis of present influences and for the design of an intervention. The pace of change will depend on the type of process to be changed. For example, it may take less time to increase the practical knowledge of consumers than to improve the social status of novel products.

Finally, it is necessary to underline the worth of a thorough diagnosis. If industrial transformation requires a behavioural change, the diagnosis will be an essential tool. The aim of the diagnosis is to specify the discrepancies between current practices and desired practices as a starting point for behaviour-based interventions, such as health and safety promotion. It is beyond the scope of this paper to discuss the various types of behaviour-based interventions. See, for instance, Geller (2001) for an excellent overview. Interestingly, many interventions try to modify a person's awareness of the values that he or she thinks are important in a given situation. This issue will be pursued below.

3. THE ROLE OF VALUES

Care about 'safety' and 'health,' respect for 'nature' and 'other people,' but also 'pleasure,' 'power,' and 'true to tradition,' are examples of the values that may guide a person's relationship with his or her environment. Values are defined as standards or criteria with which people make evaluations (Rokeach, 1973). For example, any time a person has to make a choice between a traditional 'heavy' meal and a modern 'light' meal, he or she may show the belief that one of these options is personally preferable to the other. A person's value system is his or her set of beliefs concerning preferable modes of conduct (*e.g.* 'true to tradition') or end-states of existence (*e.g.* 'healthy') along a continuum of relative importance.

Values can be studied at several levels of the framework presented in Figure 1, depending on the kind of topics that are addressed. For example, sociologists are interested in values at the level of institutions. Ethnographic investigators tend to emphasise the relatively unique cultural meaning of the criteria that specific groups, such as those believing in macrobiotics, use in a given social context. In contrast, social psychologists are more oriented to the activities of ordinary individuals; they seek to identify evaluation criteria and value structures that can be applied to, for example, the workplace or the household, but can also be generalised to a wider set of situations. This last approach is chosen here.

In this section, health and safety will be taken as examples of personal values. These topics have recently been put forward in an OECD report on environmental strategy in which the need to address the social and environmental interface of sustainability is emphasised (OECD, 2001). Interestingly, health and safety are values with both traditional and modern meanings. As a result of the process of modernisation and the democratisation of wealth (see the previous section), health and safety have become symbols of valued states of mind that imply more than just the absence of illness or injury. What these symbols currently mean can be better understood when we place them in the context of other values that are important in people's lives. Several of these values can help to increase a person's awareness of health- and safety-related issues. Others, however, can hamper this process and contribute to avoidance reactions.

The notions of evaluation criteria and value structures build on the pioneering work of Maslow (1954) regarding the organisation of human motives. Maslow saw this organisation as a hierarchy of basic needs, with self-actualisation at the top. He suggested the following list, proceeding from the lowest order to the highest: (*i*) the fundamentals of survival, including hunger and thirst, (*ii*) safety-concern over physical survival, (*iii*) desire to be accepted by intimate members of one's group and to be an important person to them, (*iv*) desire to achieve a high standing relative to others, including desires for mastery, reputation and prestige, and (*v*) self-actualisation – a desire to know, understand, systematise, organise and construct a system of values. Maslow's idea was that each higher order of motive will not function until lower levels are satisfied, at least to some degree. Conversely, this idea implies that safety-concern might be overlooked when striving to satisfy hunger or thirst, but not in striving for any of the higher-order motives (*i.e.* safety first).

Maslow's work has become popular because he is one of the writers who emphasise self-actualisation in the context of conditions and prerequisites for living a satisfactory human life. This, however, is more a cultural vision than a psychological theory. Severe hunger or fear indeed have dominating effects on behaviour, but there is little clear evidence for the differential effects of the other levels of Maslow's hierarchy. One of the problems with his ideas is that they imply fixed categories of motives. For example, the position of safety in the hierarchy depends on how it is conceived; this raises the question whether the childish need for security measures should be placed into the same category as the self-confident way in which an adult copes with risks. Instead of postulating fixed categories of motives, however, it is more fruitful to examine how people actually construct evaluation criteria and value structures.

From this perspective, it is possible to examine relationships between relatively abstract values, such as a general preference for 'security,' and more concrete values linked with a subset of situations, such as using 'self-protection' as a choice criterion in the workplace or the household. Research into consumer behaviour (Allen and Ng, 1999) indicates that values can have two kinds of impact on choices: a person's values can provide (*i*) motives for a product choice (*e.g.* why should he or she buy a product that promises self-protection?) and (*ii*) criteria that enable him or her to compare alternative products (*e.g.* which product?). In other words, values are relevant at the level of rational choices and they increase the person's sensitivity for value-related cues at the level of perceptual processes.

A highly relevant research program on values has been organised by Schwartz, who initiated a series of multinational studies on the values people find important in their lives (Schwartz, 1992; Schwartz and Sagie, 2000). To ensure that the surveys in the various countries were comparable, the populations sampled were teachers or students (*i.e.* predominantly middle class samples). Their ratings of the importance of 56 values were analysed by looking for values that seem to go together and values that lead to contradictions. Partly drawing on theory, Schwartz (1992) came up with 10 main groups of values that can be arranged along two axes (see Figure 2). The adjacent regions in Figure 2 show values that can go together, while values in the opposing regions may lead to contradictions.

The horizontal axis of Figure 2 may be particularly relevant for industrial transformation, because it is characterised by a dichotomy between being open to change versus being conservative. The openness to change relates to a number of values that go together well and are related to the desire to give one's life an independent character and to look for new things to try. In opposition to this is the priority given to tradition or conformity.

On the vertical axis, 'self enhancement' is opposed to 'self transcendence.' Self-enhancement has to do with values such as exercising power, achievement and enjoying oneself. Transcending oneself is expressed in the importance attached to being helpful and forgiving and in subscribing to universal principles — including protecting the welfare of all people and protecting nature.

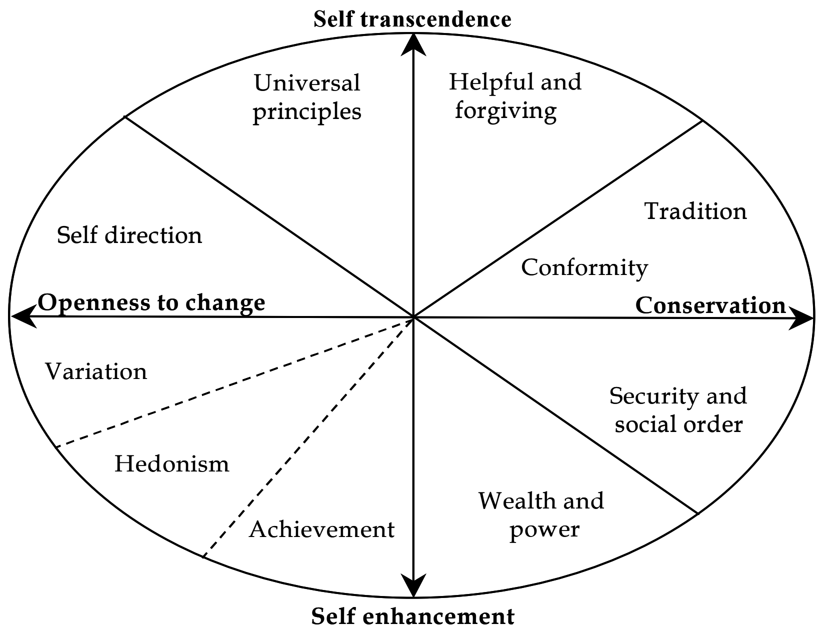

Figure 2. Main groups of values that people may or may not find important in their lives, arranged along two axes (Adapted from Schwartz, 1992).

One of the results of these multinational studies is the relationship between the value priorities of the samples and the main characteristics of the country in which they live (Schwartz and Sagie, 2000). A comparison between countries has revealed that an increase in welfare and democratisation is accompanied by attaching more importance to openness to change (‘variation,’ ‘self direction’) and to values that relate to transcending oneself (‘universal principles’). Single values that indicate universalism include: ‘protecting the environment,’ ‘unity with nature,’ ‘a world of beauty,’ ‘social justice,’ and ‘equality’ (Schwartz 1992). These values seem very much related to the modern idea of sustainable development, which combines issues such as nature conservation, worker protection and fair trade.

Another relevant point is the priority that people attach to ‘healthy’ as a value in their life. The position of ‘healthy’ is not displayed in Figure 2 because this value appears to have multiple meanings that vary among different groups of people (Schwartz 1992). The importance attached to ‘healthy’ can be:

– A goal of personal safety (‘security’ in terms of Figure 2);
– A goal of enjoyment of one’s body (‘hedonism’);
– And of health maintenance through exercise (an ‘achievement’ task).

Apparently, ‘healthy’ serves various goals, depending on how it is interpreted. These multiple meanings are also relevant for any references to ‘health’ in the context of health promotion.

The position of ‘safety’ in the context of the other values is also somewhat complicated. Schwartz (1992) used the term ‘security’ as a heading for personal goals of safety, harmony and stability with regard to one’s society, one’s relationships, and oneself. Accordingly, the term covers both family security and national security, although these might have dissimilar meanings for people from different countries. Nevertheless, it should be noted that the importance attached to ‘security’ goals seems to go well with ‘conformity’ (*e.g.* honouring parents and elders) and ‘tradition’ (*e.g.* respect for traditional culture).

The link between ‘security’ and ‘conformity’ might be reinforced by childhood experiences and social relationships. Many authors (Green, 1997; Janis, 1962; Turner and Pidgeon, 1997; Wolfenstein, 1957) have emphasised that children learn to deal with the dangers of the external world mainly through mediation of parental protection. As a result, rules of safety and rules of obedience come to be strongly intertwined, and this can have positive or negative consequences for precautionary behaviour in later life. As Wolfenstein (1957) notes, people who might be in danger should pay attention to the efficacy of precautions. If it is difficult to make an assessment of efficacy, however, their adherence to safety measures may show that they are reacting more to the enforcing authorities than to the real danger. While obedience may lead to adherence, rebellion against the authorities may lead to outspoken refusal of the precautions authorities have advised.

Accordingly, it is important to examine which values go together and which values may lead to conflicting consequences. The question of how the values connected with health and safety can be combined with the values connected with openness to change is very relevant for those transformations that directly affect consumers or citizens. The combination may have two kinds of unbalanced outcomes. On the one hand, people who endorse the traditional meanings of health and safety may be extremely reluctant to accept new technologies and novel products. On the other hand, people who are eager to change their lives may completely overlook the relevance of health- and safety-related precautions.

To create room for more balanced decision-making, several solutions have been proposed in the literature (Geller, 2001; Higgins, 1997; Langer, 1989; Weick *et al.*, 1999). From a psychological point of view, it is important to develop more positive approaches to the introduction of safety-related behaviour and to define 'safety' not only in terms of prevention of damage but also in terms of promotion of an achievement. An additional benefit of such an approach is that it might go together better with the relatively modern values of 'achievement' or even 'self-direction' (see Figure 2). The latter would be in agreement with the notion of a mindful professional who has the capacity for critical self-reflection on everything he or she does (Epstein, 1999).

Taken together, this discussion confirms the earlier point that a person's behaviour in social situations is characterised by multiple goals. It is often not feasible for people to choose just one goal in pursuit of a single value, such as safety or protecting the environment. Sooner or later, people have to find their own balance and make trade-offs. This is one of the reasons why industrial transformation should be developed and implemented in close co-operation with the people involved.

4. THE IMPACTS OF AWARENESS

Whatever values people may find important, it is essential for their achievements that they keep in touch with reality. Accordingly, the perceptual level of awareness and interpretation is basic to the 'fit' between person and environment. That people fit into their environment is often considered a precondition for their well-being. It is also an ecologically inspired ideal that people become mindful of the many connections between their society and the larger ecological community organised around natural processes (Beatly and Manning, 1997). Such an ideal seems to be embodied in certain indigenous people who have successfully avoided ecological collapse over the long term. Their awareness of the environment might be relevant for new conceptions of sustainable management, although their way of life should not be romanticised (Whiteman and Cooper, 2000). More general insights into the role of awareness for a person-environment 'fit' have been provided by two recent psychological theories that will be discussed in this section.

The ecologically inspired ideal of a person who fits into his or her environment may be characterised in terms of sensitivity and respect. For example, an indigenous beaver trapper in northern Quebec can be seen as an ecosystem manager whose sustainable practices are based on his sensitivity to the land and his respect for animals and natural forces (Whiteman and Cooper, 2000). The trapper's notion that the ice should be respected is not only spiritually motivated but also driven by the pragmatic and experiential way in which he learns from the land. A highly comparable demonstration of sensitivity and respect can be found in a rather different environment, namely among the employees of High Reliability Organisations, such as nuclear power plants (Weick *et al.*, 1999). Although the employees might not be equally motivated by spiritual beliefs like the trappers, they are just as mindful of unexpected changes in their environment and they show a comparably rich action repertoire in the pursuit of their goals.

More insights into the characteristics of sensitivity and respect can be derived from two recent theories on the level of awareness (Langer, 1989) and the focus of awareness (Higgins, 1997). Langer (1989) emphasises that the mindless way in which people frequently respond to their environment is not simply a result of the fact that a more important issue dominates their attention. People can also respond mindlessly when they don't have any important issue to think about. Moreover, the difference is not just a matter of effort. Although it takes some effort to switch from mindless to mindful information processing, the latter might not really require more effort. The main difference is that mindlessness refers to passive information processing with the expectation of no change in the environment, whereas mindfulness is active information processing with the expectation that something in the environment might change. Accordingly, it is essential for people like hunters and operators to be mindful, but this mental state might be advantageous to anyone who wants to make more of his or her life.

Another relevant distinction was made by Higgins (1997), who has analysed the different ways that people 'approach' pleasure and 'avoid' pain. His theory begins by considering what children learn about regulating pleasure and pain in interactions with their parents. What they learn is different for the two survival needs of nurturance (*e.g.* nourishment) and security (*e.g.* protection):

– Serving a nurturance need involves self-regulation with a promotion focus, sensitive to positive outcomes that might be gained (*e.g.* oriented to aspirations and accomplishments); and
– Serving a security need involves self-regulation with a prevention focus, sensitive to negative outcomes that have to be avoided (*e.g.* oriented to not making mistakes).

As a result of individual differences and momentary situations, a person may show either a promotion or a prevention focus at a given moment. With a promotion focus, the person will demonstrate eagerness to ensure the presence of positive outcomes and means of advancement; with a prevention focus he or she will show vigilance to ensure the absence of negative outcomes and mistakes (Higgins, 2000).

The distinctions regarding the level and the focus of awareness are combined in Table 1. It should be emphasised that none of the four mental states is in principle better than the others. Depending on the circumstances, each of the four might correspond with a particular 'fit' between person and environment. There are no objections against mindless processing if it is certain that the environment will not change. If changes or even small variations are relevant, however, mindful processing is required. Accordingly, the beaver trappers mentioned above seem to demonstrate flexible eagerness, whereas the operators of the nuclear power plant show flexible vigilance.

Table 1. Mental states dependent on level of awareness (Langer, 1989) and focus of awareness (Higgins, 1997)

Focus of awareness	**Level of awareness**	
	Mindless (no change expected)	Mindful (environment may change)
Prevention (no loss – loss)	Passive reliance on obligations	Flexible vigilance
Promotion (gain – no gain)	Passive reliance on accomplishments	Flexible eagerness

The differences between the four mental states of Table 1 are particularly relevant for the effectiveness of interventions that could lead to a behavioural change. A persuasive message with weak arguments, such as a simple request, may have a temporary effect on a person's behaviour in the sense that he or she will do what has been asked for as long as it is indeed a simple request. In that case, the person is mindlessly fulfilling a series of obligations; such as letting other people go first. In contrast, a person who is mindfully processing a request will need strong arguments.

The difference between prevention and promotion might be complicated by differences between the situation in which the message is received and the situation in which the message should be practiced. Higgins (1997) notes that campaigns for condom use have naturally framed the message in terms of safe sex and dangers to be avoided, which involve a prevention focus and the anticipation of losses. But at the critical moment when condoms will or will not be used, the partners are more likely to be experiencing a promotion focus and anticipating gains. Thus, according to Higgins (1997), messages with a promotion focus on anticipated gains (*e.g.*, condom use promotes a caring relationship) may be more effective in this case.

A review of research relating to the effectiveness of interventions is obviously beyond the scope of this paper. Psychology offers many strategies for promoting behavioural change (Geller, 2001; Schmuck and Vlek, 2003) and each strategy can involve one or more of the processes mentioned in Figure 1, such as perceptual, rational and social processes. Various promising strategies at the perceptual and rational level rely on recent advances in computer technology. An example is research into household energy conservation through the use of newly available and affordable technologies for relaying energy feedback information during the user-system interaction (McCalley and Midden, 2002). This is an interesting way to make users mindful of the energy they use in terms of their own goals.

A recent example of how consumers may become mindless of what they are consuming is presented in Figure 3. It appears that many people are no longer aware of the animal origin of meat. This is an interesting observation, because in discussions about transformations to a more sustainable food system, protein consumption is often singled out as a crucial problem. In particular, animal protein production creates a large environmental burden, due to a biochemically inefficient conversion (Helms *et al.*, in preparation). The fact that many people are no longer aware of the animal origin of meat is very relevant for strategies to stimulate sustainable agriculture. One interpretation of Figure 3 is that there is an increasing indifference toward the origins of proteins. This opens possibilities for novel protein foods, based on plants. However, if people are no longer aware of meat's animal origin, they will also be less inclined to pay attention to animal welfare. This may have negative consequences for attempts to stimulate sustainable agriculture by promoting high quality meat from well-treated animals. The solution will be that more attention should be paid to the segmentation of protein products in terms of bulk products and specialties.

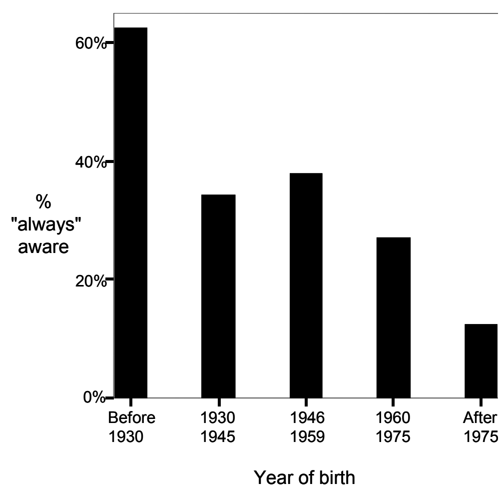

Figure 3. Percentage 'always' giving thought to the animal origin of meat according to year of birth (Hoogland et al., in preparation)

To support sustainable development it will be extremely important to identify ways in which people feel personally related to the benefits of the environment. As Macnaghten (2003) notices, the storyline of 'global nature' under threat and in need of protection from a global community has become too simplistic. Modern Westerners do not tend to think in terms of one big environment that is the same for everyone. They want credible solutions that give them the feeling that they are 'doing the right thing.' Accordingly, while for some people a promotion-oriented approach may be attractive, for others a prevention-oriented one may be preferable. In both cases, a mindful orientation to the environment is important to make people sensitive to subtle indications for a change. In modern society, this approach can only be realised if people get enough opportunities to experience the environment in a variety of ways, drawing upon their capacities for both emotional involvement and critical self-reflection.

5. FINAL REMARKS

Industrial transformation is not primarily a psychological process. Technical experts might change a technological system in a way that does not have to be noticed by the people who are using it. For example, the fact that meat is being used less frequently as a central part of the meal (*e.g.* Holm and Møhl, 2000) makes it feasible to design ready-made meals that contain less animal and more plant proteins. If the meals are being developed and prepared by retailers, and consumers can choose such a meal without thinking about the proteins, such an approach may create a substantial shift from animal to plant protein foods without much consumer involvement.

However, there are at least three reasons why such an approach is not recommendable. Firstly, there are cases in which a behavioural change can contribute to industrial transformation objectives, such as doing more with fewer materials. Secondly, it is expected that values will come into conflict in many technology-related areas, such as genetically modified food. This makes it important that all the people involved are mindful of those conflicts. And thirdly, by reinforcing mindless acceptance of technological changes people may become kind of ecological dummies, which may not be their own ideal picture of themselves.

The main message from psychologists to non-psychologists is that there are more opportunities to induce behavioural change than is commonly expected. Whether these opportunities will result in the desired end-states depends heavily on the degree to which the various determinants of behaviour can be made congruent with each other. The example of the decrease of smoking in the USA showed the combined effects of highlighting crucial dimensions of the existing culture, institutional arrangements, social norms, strong arguments to induce rational decision-making, and a straight policy to prevent mindless smoking. Accordingly, it is essential to specify as clearly as possible which behavioural change is wanted. Based on that specification, it is possible to find out which determinants of behaviour might be used for an intervention, and how they can be made congruent with each other.

In sum, the most relevant messages are:

– Human behaviour is a very flexible phenomenon, and each particular manifestation of it might be the result of many determinants;
– The determinants of behaviour can only be understood by a multi-level approach that provides insight into long-term and short-term processes;
– It makes a fundamental difference whether the consequences of behaviour are framed in a positive or negative way (*e.g.* losses are not just the opposite of gains);
– Interventions to aid a transformation should be developed and implemented in close co-operation with the people involved; and
– Whether an intervention will be successful depends on its contribution to a person-environment 'fit.'

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Chapter 3

SOCIOLOGICAL PERSPECTIVES FOR INDUSTRIAL TRANSFORMATION

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Abstract: This chapter offers a selective review of the sociological literature that is relevant to studying industrial transformation, looking at three bodies of literature. Within general and theoretical sociology, structuration theory and the sociology of networks and flows are analysed. Within the sub-discipline of environmental sociology, the contributions to industrial transformation of neo-Marxism, Ecological Modernisation, Risk Society studies and attitudes and behavioural approaches are assessed. Finally, in two domains – industrial production and sustainable consumption – we present promising perspectives for sociological analyses of industrial transformation.

Key words: social theory, environmental sociology, industrial production, sustainable consumption, sociology of flows

1. INTRODUCTION

For several reasons it is impossible to provide a full overview of sociological perspectives on industrial transformation, transition or change. Transformation and societal change are at the very heart of sociology, rather than at the periphery of the discipline. Also, as the empirical subject of industrial transformation is increasingly broadening beyond initially ‘manufacturing’ only - to include among others: consumption, agricultural systems, infrastructures, global trade, financial services, and transport

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systems – one has to review almost the entire sociological discipline. The amount of (potentially) relevant literature, studies and perspectives is overwhelming, and the scope of review depends very much on the specific research questions and what kind of selection is made. In addition, the boundaries between disciplines are being blurred, and sociological contributions to understanding social change are more and more intermingled with historical, political science, social-geographic, institutional economic and other theories, models and insights. A final complication in presenting a disciplinary overview relates to the fact that sociology is well known for its contrasting, competing and conflicting schools of thought, especially compared to economic and legal studies on social transformation. Sociologists often put forward not only different methodologies and tools in studying and understanding social transformation, but also produce diverging interpretations of similar social practices and dynamics. Any attempt to fully cover sociology's potential and actual contributions in understanding industrial transformation within the boundaries of one article will not only fail, but will also lead to a superficial understanding of what the discipline has to offer in this respect.

Consequently, this chapter does not attempt to provide such a complete overview. Instead, we will be highly selective by illustrating on three 'levels' how sociological theories and perspectives have been, are, and can be put to work to understand processes of (industrial) transformation. First we will concentrate on general and theoretical sociology, in particular on some conceptual and general sociological analyses of change. Second, in Section 3, we will pay special attention to the sub-discipline of environmental sociology, as this sub-discipline shares with most of the industrial transformation literature a strong normative view on the environment. Finally, we will provide two, more fully elaborated, illustrations of sociological analyses of change in industrial production (in Section 4) and in consumption (in Section 5).

2. GENERAL AND THEORETICAL SOCIOLOGY

One of the key issues for general and theoretical sociologists studying continuity and transformation has always been the relationship between agents or actors who trigger or obstruct transformations on the one hand, and, on the other, the structural properties of social systems that both constrain and make possible the actions and behaviour of the individual. Are (industrial) transformations to be conceived of primarily as structural or institutional change, or should they be analysed first and foremost from the aspirations, meaning and motives of human subjects trying to make a difference in the world? The classical sociologists Karl Marx, Max Weber and Emile Durkheim provide different answers to these questions (*cf.* Giddens, 1971). All three, however, tried to come to grips with the massive changes or transformations that took place right before their 19th century eyes. Marx's approach to the (great) transformation — which gave birth to modern, capitalist, industrial societies — differed substantially from the analyses of Weber and Durkheim in some crucial respects. For that reason, the discipline of sociology that they helped to establish seemed, in its early days at least, to be composed of two camps with their own journals, networks and criteria for scientific quality. Until the 1980s, the division between research based on the neo-Marxist 'Frankfurter Schüle' (Jay, 1973) and mainstream or bourgeois sociology inspired by Talcott Parsons' (1968) reworking of Max Weber, very much determined the outlook of sociologists. The views on what we would now label industrial transformations were no exception to this division.

The division between neo-Marxist and mainstream sociology, along with other rifts (sometimes parallel, but not necessarily so) between micro- and macro-studies Knorr-Cetina & Cicourel, 1981), objectivism versus subjectivism, *etc.*, gave sociology the image of a conflict-ridden discipline, with all the negative internal and external consequences related to that. Some commentators even warned that sociology could end up in a lasting crisis (Gouldner, 1971) instead of showing disciplinary growth, accumulation of knowledge and emerging consensus about the role of social scientists in studying social transformation. Against this background, the 1980s can be said to be a decade of *rapprochement*, with sociologists like Anthony Giddens (1984; 1985) and Jürgen Habermas (1981), among others, trying to build bridges between the different streams of thought. Their main effort was to update sociology conceptually in order to enable the discipline to better understand and analyse 20th century transitions within modernity. While reformulating some of Marx's ideas on social classes, evolutionism and politics, Giddens at the same time contributed to the incorporation of Marx's themes into mainstream academic sociology. With respect to the dividing lines between structuralist, macro- and objectivist schools of thought, on the one hand, and voluntarist, micro-and subjectivist schools of thought on the other, Giddens also provided an appealing compromise which helped to organise the sociological discourse in a way that it became accepted by many practitioners in the field. Roy Baskhar (1979) and Pierre Bourdieu (1984) worked along similar lines. Anthony Giddens' structuration theory emphasised the interplay between agency and structure while refusing to give theoretical priority to one over the other. Structuration theory tried to address the claims made by both structuralism and subjectivism. Structuralism emphasised the need to look 'beyond' the individual and explain transformations primarily and exclusively with the help of institutional parameters. Different schools of subjectivism or interpretative sociology emphasised the need to always relate social changes to the intentions and motives of human actors as knowledgeable and capable (change) agents. Giddens tried to do both, by arguing for the need to 'decentre' the analyses from individuals as 'subjects', but at the same time to 'recover subjectivity'. The central ideas within Giddens' conceptual synthesis emphasised social practices as units of analysis, and the notion of the 'duality of structure' to analyse the actor-structure relationship, and the concept of 'double hermeneutics' to distinguish social sciences from natural sciences. These ideas gained acceptance in sociological discipline while putting long-standing debates to rest.

Although the conflict-ridden image of sociology as a discipline in permanent crisis is no longer relevant, a great number of different theoretical perspectives still exist, providing different answers to sociology's main questions about the nature of modernity and the role of sociology in analysing transitions. Nowadays, the transformations of industrial society to post-industrial society, the changes from modernity to post-modernity, or, alternatively, from simple modernity to reflexive modernity, are the major themes of reflection and research. Distinct from most economic studies, the focus is not restricted to the economic sectors that contribute to the development of society (*e.g.* from agriculture to service sectors). In trying to identify and characterise the major transformations western societies face, sociologist focus on all the major (clusters of) institutions or sectors of modern societies: the market and economy, the state and state organisations, science and technology, cultural and civil society institutions. Among sociologists a vivid debate has emerged as to what institutions should be regarded as the core institutions that give society its specific 'modern' character. Which clusters of institutions do we have to take into account when trying to understand the overall transformation processes that are going on? What kind of criteria – economic, political, cultural – do we need for assessing how far these transformations have already emerged in different countries? Is it within the 'industrial-technological' dimension of societies that we have to find the most decisive dynamics — as argued by industrial and post-industrial society scholars such as Daniel Bell (1976), Alvin Toffler (1981), Richard Badham (1986), and Boris Frankel (1987)? Or is it, rather, the 'capitalist' character of modernity that explains its extreme (growth) dynamics, as argued by Marxists and sociologists working in the political economy tradition? Are transformations in the organisation of production and consumption in modern societies first and foremost the result of science and technology (as argued by the so called 'counter-productivist' scholars such as Andre Gorz (1989), Otto Ullrich (1979) or Ivan Illich

(1972)), or is it the cultural and value dimension that should be held responsible for the changes (Inglehart, 1987)? Or maybe all these dimensions and institutions have become integrated and interdependent to such a great extent that it is no longer possible to identify one institutional cluster taking priority over the others (as argued by modernity and post-modernity scholars such as Jürgen Habermas (1987), Francois Lyotard (1983), Jean Baudrillard (1983), and, again, Anthony Giddens (1990)). Kristian Kumar (1995) provides an excellent overview of the contributions various authors made to the debate on the basic characteristics of modern industrial, capitalist societies, and the major transformations in their production-consumption structure over the last two hundred years.

Recently, especially from the 1990s onwards, the theme of globalisation has become prominent on sociology's research agenda. And with that, the character of transformation-studies has changed somewhat. While up till the 1980s the unit of analysis for understanding change and transformation had been the nation-state, this unique focus on the nation-state was challenged by globalisation. New concepts and theories emerged when (environmental) changes and transformations were no longer to be identified (only) at the level of the nation-state, but increasingly between, outside and beyond national economies and societies. Processes of globalisation bring fundamental changes to the very nature of modern societies. To grasp the new dimensions of global modernity, and to understand the changes that take place through information and communication technology systems through flows of global capital and through supranational political arrangements, the central position of the nation-state in sociological analyses had to be broken down. Sociology could no longer focus on the national systems of accumulation, the national systems of government, the national systems of innovation, the national industrial structure or national cultural values. The work of Manuel Castells (1996; 1997a; 1997b) on the network society, and of John Urry (2000; 2003) on the sociology of mobility, represent some of the new lines in sociological analysis, blurring even more the disciplinary boundaries between the social sciences. The title of Urry's (2000) book on modernity – '*Sociology Beyond Society*' – is instructive in this respect.

How do these studies and theories in sociology relate to the field of industrial transformation? First, most of the contributions are aimed at assessing, understanding and interpreting social change, rather than taking the normative and design perspective that is so common in industrial transformation studies. The main emphases within sociology are on:

– Defining the nature of continuity and change (what is changing and what remains stable, what kind of indicators can be used to visualise and indicate the transformations?);

– Understanding how these changes take place (what are the main agents triggering change, and which structural properties of social systems enable or constrain transformations?);
– Identifying the consequences of these transformations for the properties of modern societies (distributional aspects with respect to resources, democracy, changing power relations, *etc*.); and sometimes also
– Engaging with social movements and oppositional groups in criticizing undesirable consequences (*e.g*. critical theory, neo-Marxist sociology).
– Although there are exceptions, theoretical sociologists are less preoccupied with designing desirable future societies or social systems (*e.g*. the industrially transformed society).

The second striking characteristic of general and theoretical sociology is that most social theories hardly pay attention to the physical dimensions of social life, or what has been labelled as the sustenance base to social life. Consequently, environmental deterioration and reform (also within the form of industrial transformation) have not really been emphasised consistently. Only from the late 1970s onwards does one witness a small but growing number of sociologists arguing for the need to bring an ecological paradigm shift to the social sciences, resulting in the establishment of 'environmental sociology.'

3. ENVIRONMENTAL SOCIOLOGY

Put simply, environmental sociology analyses how the organisation of society and man-man relations affect the relationship between (wo)men and nature. Methodologically, conceptually and theoretically, environmental sociology obviously leans heavily on the larger sociological discipline, while sharing at the same time some basic characteristics with what we can label as environmental studies. Many of the theoretical positions and debates from general and theoretical sociology are reflected in environmental sociology. While the emphasis is on understanding and interpreting (changing) social practices and institutional developments (especially, of course, those that have direct relevance for the sustenance base), within environmental sociology there seems to be a stronger normative outlook when compared to general sociology. Environmental sociologists very often engage in discussing and designing future institutions and practices with an eye to meeting sustainability criteria. For some, this commitment takes the shape of vividly criticizing unsustainable practices of production and consumption, while other schools in environmental sociology focus on and engage with best practices, social experiments and the furthering of sustainable institutional developments and policies, sometimes in the margin of mainstream social systems.

Our selection of contributions to the field of environmental sociology reflects these different forms of commitment. Some themes are strong on theoretical analyses of environment and modernity, while others represent a large body of empirical work as well. When taken together, we think the themes typify the most important contributions and debates in the international networks of environmental sociologists that have relevance for industrial transformation.

The treadmill of production

Neo-Marxist environmental sociology has concentrated its studies and analyses especially around the treadmill of production (*e.g.* Schnaiberg, 1980) and the second contradiction of capital (O'Connor, 1996). Both lines of study focus especially on the continuity of the capitalist character of modern production and consumption systems, which are consistent in jeopardizing the environmental sustenance base that supports these systems. Studies and analyses in this tradition consequently point at the difficulties – or in fact impossibilities – of transforming the current systems of production and consumption due to the inherent structural capitalist character of these systems. Sophisticated analyses point to the symbolic or window dressing character of any transformation as far as environmental change is concerned. Although it is acknowledged that changes might occur in environmental policies, in environmental consciousness, in levels of support for environmental NGOs, and in new environmental technologies and management systems, it is argued that these changes do not affect the fundamental patterns of accumulation and exploitation. The material basis of production and consumption remains intact. There is, according to these studies, a direct and fundamental relation between the industrial-capitalist mode of production on the one hand and ongoing environmental deterioration on the other. As long as technologies and policies do not affect and alter the industrial-capitalist character of production-consumption systems in modern societies, there will not be any lasting and significant improvement in environmental consequences.

Ecological modernisation

The ecological modernisation school of thought has been developed partly in reaction to the overall pessimistic (in terms of the possibilities to overcome environmental crises) and structuralist outlook characterizing the neo-Marxist perspective (*cf.* Huber, 1985; Spaargaren and Mol, 1992).

Ecological modernisation theory developed concepts and understandings on what it calls the emergence of ecological rationalities, interests and perspectives in organizing both production and consumption. Instead of focusing on structural continuity, ecological modernisation theorists orient themselves towards analysing environment-informed changes in social practices (*e.g*. leisure, buying food, transporting) and institutional developments (in markets, state institutions, scientific institutions *etc*.). Basing its theoretical work especially on industrial production in Northwest European countries, this school has expanded its empirical studies also towards Asia and the USA, and towards consumption and more comparative, supranational and global studies of institutional reform. Most of the work in the ecological modernisation tradition is firmly rooted in sociological theories, especially Giddens' structuration theory, reflexive modernisation theories, consumer sociology and globalisation theories (Spaargaren, Mol and Buttel, 2000). Political scientists especially have worked on a related theory of political modernisation (*cf.* Jänicke, 1993; Tatenhove *et al.*, 2000), drawing more on political science and policy science theories.

Risk society studies

Whereas ecological modernisation studies and theories have especially focused on the transformation in actual practices of production and consumption, risk society studies are associated with studies on transformations in science and technology, on changing relations between scientists and lay actors, and on the growing and institutionalised uncertainties one is confronted with when dealing with environmental problems and controversies in the current phase of modernity. Following Ulrich Beck's (1986) influential '*Risk Society*' thesis, a large number of studies sought to address not only the new types of environmental risks (notably so called High Consequence Risks like global warming), but also the changes in the institutions of late modernity, which have to deal with these new risks. Brian Wynne (1982), Elizabeth Shove (2003), and their colleagues at Lancaster University lead a growing number of studies illustrating the fact that the role of science, scientists and scientific evidence is no longer unproblematic. After the 'disenchantment of science,' we have to look for new perspectives for dealing with scientific knowledge, while giving more emphasis to the role and significance of lay actors and their experiences and knowledge. In some respects, risk-studies downplay the importance of science and technological arguments, evidence and institutions in processes of 'industrial' change, pointing out the intrinsic connections between scientific and other social actors and factors. Participation, participatory policy analysis, participatory integrated assessments and the like are all in line with this sociological tradition. To some extent, risk studies can be said to be related to the sociology of science and technology, sharing an interest in analysing the ways in which modern societies deal with Bovine Sponingform Encephalophathy (BSE)[5], Genetically Modified Organisms (GMOs) and other risks that are difficult to sensitise and escape (Oosterveer, 2002).

Attitude – behaviour studies and the social practices approach

The role of human agency in bringing transitions about is recognised by many as important, but the relationship between individual behaviours, lifestyles and interests on the one hand, and structural, institutional developments on the other, has been the subject of heated debate in the environmental social sciences as well as in general sociology. In the 1970s and 1980s, the dominant model used to study environmental behaviours was the attitude-behaviour model introduced by Fishbein and Ajzen (1975) in the field of social psychology. The behaviour of individuals was predicted from their attitude towards the environment. The interplay between individual behaviours and social structure was hardly given attention in this model, and if structure was brought into play, it was as a constraint to individual choice only. Although numerous theoretical and methodological elaborations and improvements were made over the years, in the end the attitude-behaviour model did not live up to its promises, *i.e.* it turned out to be rather difficult to predict environmental behaviours from peoples' attitudes only (Spaargaren, 1997). For that reason, an alternative theoretical model was developed within environmental sociology to organise research on the lifestyles and behaviours of individuals. This 'social practices model' or approach was derived from structuration theory as developed by Anthony Giddens in the 1980s (Section 2). A basic characteristic of the model is a combined emphasis on individual and contextual factors, which are both involved in the structuring of social practices (dwelling, sporting, cooking, gardening) that groups of individuals adhere to in daily life. Although the model inspired research projects on the politics of sustainable consumption in several countries (*e.g.* Martens and Spaargaren, 2002; Goldblatt, 2002), empirical studies in this tradition are still low in number when compared to the attitude-behaviour paradigm.

[5] Bovine Sponingform Encephalophathy (or mad cow disease)

4. ENVIRONMENTAL SOCIOLOGY AND INDUSTRIAL PRODUCTION

Environment-informed industrial transformations do not unfold automatically. To understand how individual companies, industrial sectors, industrial estates and industrial systems take environmental considerations into account, we need to be more specific on the roles various (industrial and non-industrial) actors play in distinct settings. Network models that relate industrial firms to the societal, economic and policy environment are useful sociological tools of analysis.

Network analyses are worth considering for several reasons. First, they form an intermediary perspective that links rather abstract social-theoretical notions with empirical developments in social systems of production and consumption. A second reason is of a more theoretical nature. On the 'continuum' of action theory and system theory, network models occupy a middle position and offer a more fruitful theoretical perspective than either of the other theories. Both (voluntarist) action theory and (structuralist) system theory have their limitations as conceptual models, as has been elaborated above in dealing with structuration theory. With their institutional analysis, network models can be interpreted in line with the structuration perspective. Thirdly, the empirical scope of network models corresponds well with the main aim of industrial ecology and industrial transformation perspectives, which is to identify (and contribute to) institutional changes in relation to improving environmental performance.

In other words, network models have the advantage of combining both the structural properties of institutions and the interactions between actors making up a network. Networks can be characterised as social systems in which actors engage in more or less permanent, institutionalised interactions. If we apply a network perspective to industrial transformation and industrial ecology, the following three types of network models can be distinguished analytically:

- Policy networks; within policy networks, interactions and institutional arrangements between state organisations and industry are primarily governed by political-administrative rules and resources. Policy network studies analyse the interdependencies between these actors, the 'rules of the game' which put these policy networks to work, the resource dependencies (regarding power, money, knowledge, information, *etc.*) between the various actors and agents dominant in these policy networks, and the common or diverging world view along which communication and joint strategies are developed or not developed. There exists a considerable amount of literature (*e.g.* in neo-corporatism and policy community studies) that provides evidence of the usefulness of analyses of the transformations and continuities in these interdependent network actors (*e.g.* Grant *et al.*, 1988; Marsh and Rhodes, 1992; Smith, 1993; Mol, 1995);

– Economic networks basically focus on economic interactions via economic rules and resources that are shared between economic agents in and around the industrial park, chain or sector (or whatever object and unit of analysis). Although the intellectual background of economic network analyses are mainly to be found in industrial organisation theory, institutional economics and organisational sociology, the basic concepts differ only partially from those in policy network analyses. Economic network studies analyse the relationships between the firms, the network structures in terms of power and resource dependencies, and the economic processes of continuity and transformation. They look at (*i*) the vertical interactions from raw material producer up until the final consumer and beyond, (*ii*) the horizontal relations between competitors and on the level of the industrial branch association providing some collective interest representation, and (*iii*) regional relations and interactions in restricted geographical areas. The relations with conventional industrial ecology analyses of the material flows in geographical areas or production-consumption chains (*e.g.* LCA) are evident, but in network studies the emphasis is on the non-material dimensions of the park/chain/network (economic relations, power, information monopoly and exchange, knowledge, control, ownership, *etc.*). Håkansson (1988), Martinelli (1991) and Grabher (1993) are relevant volumes that provide valuable conceptual tools for analysing these economic networks in detail;

– Thirdly and finally, societal networks aim at identifying relations between the industrial park, chain or sector in question and civil society organisations and arrangements associated with what is usually called 'the life world,' both directly and indirectly via state agencies. It is the rich tradition of (new) social movement research that provides the conceptual tools to analyse the interaction patterns, and their continuity and transformation, between on the one hand environmental and consumer organisations and on the other industrial firms. The volume by Anheier *et al.* (2001) looks into the dynamics of global civil society from a sociological point of view.

These three network models are more or less brought together in the triad-network model (*cf.* Mol 1995). The triad-network model is a conceptual model for analysing the extent to which the ecological 'perspective' penetrates and transforms the social practices predominately governed by the three basic perspectives in modern society: the political, economic and socio-cultural. It enables one to analyse to what extent an ecological perspective (and thus ecological interests, arguments, considerations, *etc.*) 'makes a difference' in organising production and consumption, independently from the other three perspectives/orientations. Each of the three interdependent networks thus constitutes a combination of a specific analytical perspective, distinctive institutional arrangements and a restricted number of interacting (collective) actors, which are considered to be most important regarding that perspective.

Such a model helps us to understand why industrial ecology and industrial transformation initiatives are taken, whether and how these initiatives are successfully institutionalised, and how such modalities of environmental reform affect and change the existing structures and arrangements. The study of Van Koppen and Mol (2002) on eco-industrial parks (EIPs) illustrates that these interdependent networks and mechanisms do not work in a similar way, or with equal 'force,' or with comparable outcome at every place on the globe.

5. SOCIOLOGY AND SUSTAINABLE CONSUMPTION

Within general sociology the phenomenon of consumption used to be connected either to a generalised critique of modernity – in the tradition of the so-called 'Frankfurter Schüle' – or to post-modern perspectives on consumerculture. Only since the late nineteen eighties has a sociological perspective on consumption been developed which pays adequate attention to the process of consumption itself (*cf.* Warde, 1990). Consumption is sociologically approached as the process of handling products, images and signs in order to meaningfully constitute and reproduce our daily lives and the lifestyles attached to them. In their influential book on 'the world of goods' Douglas and Isherwood (1979) convincingly argued that economic and psychological models of consumption behaviour only tell us part of the consumption story, as consumption has an inherently social and symbolic nature. In addition, sociological analyses of consumption can contribute to the debate on industrial transformation by complementing the overall technical outlook, which is characteristic of many environmental science-based analyses of transitions.

The analysis of sustainable consumption and lifestyles was put on the agenda by environmental sociology to fill the gap between general sociology – neglecting the environmental aspects of consumer culture – on the one hand, and the environmental sciences – neglecting the social or symbolic dimension of cleaner consumption – on the other (Cohen and Murphy, 2001). Since again it is impossible to present the full picture of this scientific domain, we will single out two topics, which have proved to be of special relevance to industrial transformation studies.

The social or symbolic dimension of goods and services

Sociology can make an important contribution to industrial transformation studies by showing the consumer-driven nature of changes in production-consumption cycles, and by connecting these consumer-behaviour-based drivers to the overall social and symbolic structures of societies. As such they complement economic approaches that focus on the economic dimensions of consumption. The notion of chain-inversion (*i.e.* the consumer-end of production-consumption chains increases in power vis-à-vis the production side) as used in studies on the post-Fordist organisation of modern production and consumption practices, can only be properly assessed if the analysis takes into account where the (lack of) consumer preferences for green products and services and eco-labels come from, and how these preferences are embedded in their daily lives and social cultures.

In '*The World of Goods*' Douglas and Isherwood (1979) opened a debate with economists and their models of predicting consumer behaviour. They criticised the individual preference models of economists mainly on two grounds. First, these models fail to effectively address the fact that most of the time products come to the consumer in 'clusters,' instead of one by one. Second, economic models do not pay any attention to the symbolic or social dimension to consumption. The 'drivers' behind consumption behaviours can only be understood, according to Douglas and Isherwood, if one recognises the important fact that people consume products and services not as ends in themselves, but because they want to relate meaningfully to fellow citizen-consumers. Only by investigating this everyday-life process of human agents socially positioning themselves with other people, can one come to an understanding of why people want goods. We will first discuss the social and symbolic dimension of consumption to take up the first criticism based on the 'clustered' nature of consumption-items in the next section.

Douglas and Isherwood discuss the social and symbolic dimensions of consumption against the background of Veblens' famous concept in sociology of 'conspicuous consumption.' This concept connects consumption first and foremost with showing off and displaying higher status when compared to other people. Also, in the contemporary work of Pierre Bourdieu (1984) on consumption, it is 'distinction' and (class-bound) rivalry between social groups that are regarded as the main dynamics behind consumer behaviour. While not ignoring these competitive forms of social positioning, Douglas and Isherwood point to the crucial importance of the social mechanism of 'keeping to the level' as the dominant way in which actors position themselves *vis-à-vis* relevant others. People routinely 'keep in touch' with changing norms of what is 'normal' or 'appropriate' behaviour for the different daily consumption practices they are involved with. One just has to look at the clothing behaviours of high-school teenagers to know how powerful these mechanisms can be. What counts as 'normal' of course is different for different regions of the world, variations still being strong between nation-states and socio-economic classes.

To investigate the chances for successful innovations in terms of new industrial processes and products, the analyses should not be restricted to the classical criteria of price, the use-value and (environmental and status) quality of the products and services. Investigations on environmental innovations should also focus on the ways in which new, more sustainable products and technologies do or do not 'fit' into the existing norms on Comfort, Cleanliness and Convenience (CCC) (Shove, 2003) that govern our daily lives. These CCC levels are known and used by human agents in a routine, practical way and are reproduced in the context of the consumption practices they enact when performing their 'normal' lives. These standards or guidelines for keeping to the level can be investigated both on the individual level of the personal lifestyles of people as well as on the group level of shared social practices. For environmental sociologists, the latter option for studying CCC norms is more attractive since it enhances the possibility to study the impacts of the social structures, which form the 'infrastructures' of consumption practices. Infrastructures of consumption refer to the networks of producers, advertisers, distributors and retailers our shopping teenager meets when seeing a new shirt. When buying it, the teenager can be said to reveal the peer group preferences, which the providers are so keen to know and serve.

The infrastructural view of consumption

Studying consumer decisions on the level of individual products or behavioural strings fails to note the interconnectedness of products and services as brought about by both consumers themselves and through the systems of provision involved in the delivery of the packages. To provide an alternative to 'reductionist' views (Princen *et al.*, 2002) on consumption, the infrastructural perspective on consumer behaviour was developed (Fine and Leopold, 1993; Spaargaren, 2003; Van Vliet, 2002; Shove, 2003). These perspectives put at the centre of analysis the relationship between individuals and social structures. In many infrastructural studies, the central aim is to try and find out where the voluntaristic freedom of choice or the relative autonomy of individuals ends and where the constraining influences of social structures begin. As explained in Section 2 however, we think that the question of 'the freedom' of the individual *vis-à-vis* social structures should not be analysed in just one direction, *i.e.* the way in which individuals are constrained by social structures. This 'deterministic' view of human agency is only half of the story, since human actors themselves also influence social structures while organizing their daily consumption practices (see Section 2). Structures are both constraining and enabling for human behaviours, and they are open to change. We will try to illustrate this two-way process by looking into one specific field of empirical research: the domestic consumption of energy, water and waste-services.

Within environmental sociology, a number of international, comparative studies have been conducted, illustrating the usefulness of the infrastructural perspective (Chappels *et al.*, 2000). Since energy, water and waste-services are connected to the environmental impacts of consumption practices in a very direct way, it is not surprising that the (utility) sectors involved in the provisioning of these goods and services are at the centre of these analyses. The Norwegian sociologist Per Otnes (1988) discusses everyday domestic consumption routines from the perspectives of both the interconnectedness of individual households and the collective, socio-material systems providing energy, water and waste-services to those households. When people tap water for making tea, showering or cleaning up the house, they turn themselves into consumers of the drinking water system as it operates before the water-meter. While being serviced by this water system, they at the same time are 'servicing' the water (expert) system, since they are involved in its reproduction. Most of the consumption practices in the house are routines, conducted without much conscious consideration. When the water or energy systems break down, a de-routinisation of domestic social practices will be the result, opening up the possibility to discuss among occupants and representatives of the (utility) systems, the conditions for a future re-routinisation of these consumption practices. De-routinisation of course can also be 'enforced' by parties on both sides of the (water or energy) meter when, for example, new meters are installed, when people move to a new house, or when occupants are confronted with the possibility or need to choose between different providers as a result of privatisation and liberalisation of electricity markets.

From the research conducted with the help of this infrastructural perspective on (domestic) consumption, a number of conclusions can be drawn which have specific relevance for (future) research and policies on industrial transformation:

– Transition processes can and should be studied at different levels, ranging from the micro-level of individual niche project and technologies

via the meso-level of socio-technical regimes up to the macro level of the socio-technical landscape (see chapter by Geels in this volume);
– While using different levels of analyses, preferably at the same time, the interconnectedness of the processes and mechanisms operating at different levels should be emphasised. While for example the major dynamics of liberalisation processes will be assessed at higher system levels to a considerable extent, these are mirrored in processes at the level of daily behavioural domestic routines: differentiation in products and providers will in the end result in differentiation in lifestyles and patterns of domestic consumption;
– The role of individual human agents in transition processes is neither to be described in terms of passive, deterministic recipients of changes shaped at higher system levels nor in terms of free floating architects creating social structures *de novo*; and
– The cultural dimension of transition processes is as important for understanding the range of possible futures as the technological systems implied in the transition.

6. EPILOGUE

In most industrial transformation studies, sociological contributions tend to be subordinate to environmental studies, environmental sciences or technological analyses and framings. No matter how ‘human’ the International Human Dimensions Programme on Industrial Transformation claims to be, environmental sciences and studies constitute its dominant paradigm. One of the reasons for this is the fact that sociologists for a long time made little or no effort to include the natural environment in their analyses and understandings of social change, notwithstanding the work of a small group of environmental sociologists which tried to develop a new ecological paradigm also within the social sciences from the 1970s onwards (*cf.* Dunlap and Catton, 1979). However, with environmental sociology gaining ground in the 1980s, and especially with the development of ecological modernisation theory into a prominent sociological perspective during the 1990s, this situation has changed for the better. Nowadays, a growing number of sociologists take ‘factor-four type’ of processes of environmental change as their central objective, and they are willing and conceptually able to make substantial contributions to the industrial transformation research.

In presenting a selective review of the different approaches to social transformation studies as developed within (environmental) sociology over the past decades, we have illustrated the value of sociological analyses in understanding, interpreting and designing industrial transformation. Although sometimes rivalling with respect to their basic assumptions, domain of relevance and limitations and strengths, we argued that the different sociological approaches have become accepted as valuable contributions to the field of environmental social change.

The recent attempts to develop sociology of networks and flows by, among others, John Urry (2000; 2003), could bring this achievement one step further. With respect to the main argument of this chapter, the relevant innovations of the sociology of networks and flows are not so much to be found in its conceptualisation of globalisation, complexity or actor-structure relations. What is especially relevant is that this emerging perspective offers a new and promising conceptualisation of the classical theme within the (environmental) social sciences: the interrelation between the 'social' and the 'material.' Networks and flows are defined and analysed in terms of their social and material dimensions at the same time. As such, the sociology of networks and flows puts itself in between the strong natural science based material and ecological flow analyses that still dominate contemporary environmental studies, on the one hand, and the 'oversocialised' sociological perspectives on the environment on the other.

Environmental study scholars might interpret this as just another attempt at integration and interdisciplinarity. It should be noticed, however, that we are dealing for the first time with an attempt at integration of natural and social sciences on the conditions of and formulated by a *social science* theory of transformation and change. It is this emerging school of thought in sociology that we identify as one of the most promising sociological contributions to industrial transformation in the near future, notwithstanding all the (conceptual and operational) difficulties that might come along with it (*cf.* Mol and Spaargaren, 2003).

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Chapter 4

INDUSTRIAL TRANSFORMATION AND INTERNATIONAL LAW

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Abstract: This paper examines how international law can promote industrial transformation. In order to do so, it presents in ideal typical terms how international law actually evolves and the factors that influence its evolution. This is done to show that if one wishes to promote industrial transformation using international law, then one needs to influence the factors that actually influence the evolution of international law. The paper concludes that although international law is essentially conservative, it has on many occasions been a driving force for change.

Key words: international law, industrial transformation, water law, climate change law, the law of sustainable development

1. INTRODUCTION

Law is generally never revolutionary in nature; it is mostly evolutionary, growing gradually and reflecting the existing norms in society. This chapter, in line with the theme of this book, reflects on the question: How does law contribute to industrial transformation, or put differently, how can law and legal processes be used as a tool to influence industrial transformation? In addressing this question, this chapter deals with international law since domestic legal systems vary considerably and since, in the age of globalisation, international law and policy is expected to have considerable influence on domestic legal systems and vice versa. It is important to

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emphasise, however, that international law does not exist in a vacuum, and that international law has generally served to harmonise existing national laws and provide a level playing field at the international level. Having said that, in relation to the modern challenges faced by the global community such as climate change and loss of biodiversity, international law may in many cases precede the domestic articulation of the laws (Gupta, 1997). This inevitably implies that while the analysis that follows will centre on international law developments, there will be moments when one may be able to speculate on domestic legal developments and their relationship to international law.

This chapter, in its attempt to assess legal contributions to industrial transformation, will analyse how international law evolves over time as well as what factors influence this evolution. It looks at the tools used in the legal process, principles, rights, responsibilities, and non-compliance mechanisms, to show how the combination of these tools and principles provides incentives and disincentives to societies to adopt more sustainable production and consumption patterns. While this chapter examines international law and policy issues, it does not limit itself to a purely legal analysis.

Let me begin with a few introductory words about the law. In order to be effective, law must reflect general social consensus on the need for the law (*e.g.* fairness, constitutional validity, legality and legitimacy) and must be supported by judicial remedies (*e.g.* penalties, access to judicial remedy). This is why law has been traditionally based on social customs and religion. Many of the core values in modern law can be traced back to the religion or cultural values of a society (*cf.* Caponera, 1992) even though the complex evolution of the law makes the connection somewhat difficult to make. This implies that there are limits to the way in which we can use national and international law and its tools to promote industrial transformation in a society. Changing legal systems exogenously without taking into account the deep roots of legal systems is likely to fail. I am not arguing that law cannot be used to change society but that it would be wise to remember that there is a subtle and complex relationship between society and its legal structure, and they move symbiotically forward (*cf.* Mohammed-Katerere and van der Zaag, 2003; Singh, 1991; Gupta 2004).

Furthermore, today we have 196 national legal systems across the globe; they share many similarities and yet they have many differences because they are contextually rooted (Gupta, 2004). Harmonising these laws through international law to provide incentives for social change is a very attractive prospect for some policy experts, and this has led to a large number of international initiatives. The compliance-pull or effectiveness of many of these laws, however, has been weak precisely because of the alien nature of these laws apart from the lack of capacity to implement these agreements (*cf.* Young and von Moltke, 1994; Sands, 1992; Jacobson and Weiss, 1995; Keohane *et al.*, 1993; Birnie and Boyle, 1992).

In contrast to national legal systems, international law does not have as long a history, although treaties in the area of water law go back to biblical times. International law recognises three sources of law: custom, convention (or treaty law), and the general principles of law often emerging from secondary sources of law such as judicial decisions, codifications, and legal treatises, *etc*. (Article 38 of the Statute of the International Court of Justice) International law is based on the constitutional idea of the sovereign equality of states and that states bind themselves to international law through consent (Article 2 of the Vienna Convention on the Law of Treaties).

International law is fundamentally addressed at states (and sometimes international organisations) and aims to promote cooperation between states. International law traditionally does not address individuals or business enterprises and, hence, does not have a direct influence over them except through the processes by which a state ratifies and actually implements an agreement.[6] As such, the purpose of international law is not to provide direct incentives to individuals and organisations (these are not the subject of international law), but to provide incentives to states to participate in international problem solving. In other words, international law provides at best an indirect stimulus to individuals and companies. Thus, although the United Nations Framework Convention on Climate Change of 1992 and the Kyoto Protocol of 1997 do include opportunities for private sector participation in the implementation of the agreement, the private sector is unlikely to participate unless their home countries are parties to these agreements. As such, the tools available to international law are limited and indirect.

At the same time, it is important to mention that since international law is less developed than the legal systems in many developed countries, '…the development of international law as a system and the development of legal tools and techniques to deal with new issues such as sustainable development go hand in hand.'[7] This implies that creating incentives for industrial transformation at the global level is accompanied by the process of developing international law itself, and that the process is more challenging because there are no clear-cut precedents or frameworks for doing so. This is a continuously evolving process. Against this background, this chapter tries to present an internally consistent and coherent picture of the way law

[6] There are some Conventions such as the 1965 Convention on the Settlement of Investment Disputes between States and Nationals of Other States that focus on nationals.

[7] My thanks to Marcel Brus for this comment.

contributes to industrial transformation. It might also be fair to mention that I do not take a Eurocentric view of international law, but try to develop a more cosmopolitan perspective.

Although theories on international law and relations go back to 1st century *A.D.* India (Rangaranjan, 1987), modern international law can be traced back to the Spanish jurists Vitorria and Suarez and the Dutch jurist Grotius. Although essentially influenced by Western precepts, it is the 1945 UN Charter and the Statute of the International Court of Justice that define the international legal system as it currently stands. The UN Charter not only provides the organisational context for international law making, it also clearly calls for the progressive development of international law. The need for new regulations and rules has again been emphasised at the 1992 UN Conference on Environment and Development (Agenda 21, 1992) and the 2002 World Summit on Sustainable Development (WSSD, 2002).

A reflection on the last fifty years of international law making reveals that there are three ideal-typical ways in which the law has developed and, hence, influenced both incremental changes and structural transformation. The three ideal-typical models could be labelled as follows: the *incremental model* of the progressive development of international law, the *structural model* of the progressive development of international law and the *regulatory competition* model.

Before delving into an explanation of the three models, it might not be irrelevant to explain that all law development at the international level moves from soft to hard law and then gradually becomes part of customary international law. While there is no universally accepted definition of soft law, Shelton argues that soft law consists of '…normative texts, not adopted in treaty form addressed to the international community as a whole or the entire membership of the adopting institution or organisation.' (Shelton, 1997: 120). She divides soft law into primary and secondary types, where primary soft law calls for the establishment of new standards, reaffirms previously accepted standards in legally binding or non-binding documents, or further elaborates previously accepted vague or general texts. Secondary soft law consists of recommendations, jurisprudence and decisions of specialised bodies established under international law. In contrast, hard law is legally binding and can only be made by states and international organisations when the rules of procedure are duly followed (see also Birnie and Boyle, 2002: 16).

Generally, at the international level, when new ideas and principles are developed and articulated, they are initially adopted in political declarations and resolutions. Such principles are referred to as soft law. How do these soft law norms develop? They develop through the processes of interaction, interpretation and internalisation by state and non-state actors (Koh, 1997).

Civil society increasingly plays a critical role in developing and shaping these norms through their discussions and interpretation of the law (Cover, 1983). Because civil society is closely involved with the state in discussing, debating and developing norms and their interpretations, it is also interested in having the norms adopted. Once norms develop, they are sometimes adopted at the political level in declarations and resolutions, and over some years may develop further into legal norms in binding legal documents. The norms then shape human behaviour. As more and more treaties adopt the same text, the principles become part of international customary law. The following section presents a description and analysis of the observed phenomenon of law making at the international level.

2. THE INCREMENTAL MODEL

The incremental model refers to the slow and gradual evolution of international law. As a law develops, new incentives are provided to society, and societies respond to these incentives. Two examples of this incremental evolution are presented below – one focuses on international water law and the other on the international law of sustainable development.

International water law

Countries have been dealing with international river basins throughout history. The issues related to sharing water are critical in many respects, and historically each region has developed its own legal system to deal with the problems that arise. Given the many conflicts and solutions developed in different parts of the world, the UN General Assembly requested the International Law Commission (ILC) to prepare an international law on water in the 1960s. This action was inspired by Article 13(1) of the United Nations Charter (1945) which states: 'The General Assembly shall initiate studies and make recommendations for the purpose of: (a) promoting international co-operation in the political field and encouraging the progressive development of international law and its codification….' 'Narrowly defined, codification involves the setting down, in a comprehensive and ordered form, of rules of existing law and the approval of the resulting text by a law-determining agency.' (Brownlie, 1990: 30)

In the meantime, the International Law Association (ILA), a body of legal academics, prepared the Helsinki Rules on the Uses of Waters of International Rivers in 1966. This document was expected to reflect the existing state practice (how countries and societies give effect to the law) in different parts of the world, and possibly the ideals of some of the members who wanted to codify water law. Since state practice differed considerably in different parts of the world, this document attempted to resolve some of the conflicts by choosing the most commonly prevalent principles or, in some cases, choosing one principle in preference to another. The document has no formal legal status but became influential since it was subsequently used as reference material in many regional water treaties (*cf.* Caponera, 1992; Bourne, 1996). In other words, the document was seen to reflect an objective evaluation of the legal situation at that time, and thereby began to influence state practice especially in many developing countries. The major shortcoming of the ILA document, however, was that it focused primarily on water sharing[8] since that was the dominant preoccupation of states at that time.

The ILC took more than twenty years to complete its drafting task, and presented a text to the UN General Assembly in 1991. In 1994, the General Assembly invited states to present their written comments on the text by July 1996 and in 1997 the UN Convention on the Law of the Non-Navigable Uses of International Watercourses (IWC - International Watercourses Convention) was adopted. Most of the elements of the ILA document were reflected in this new document, but some new environmental aspects were also included. This document has, however, not been ratified by a sufficient number of states to come into force. There are, at present, three schools of thought about this. According to one school of thought, the lack of ratification reflects the fact that there is inadequate support for the various principles, and that it is only state practice and court jurisprudence that will ultimately indicate which of the principles have become part of customary law. This is the view of many countries that have not ratified the agreement. According to others, the document reflects state practice and, hence, customary international law; therefore, ratification *per se* does not increase the legal status of the principles in the document. The third school of thought argues that the law is in fact influential and a model law since its text serves as inspiration for new laws, such as the 2000 South African Development Community Revised Protocol on Shared Watercourses negotiated between 10 countries, which entered into force in 2003 (*cf.* Nollkaemper, 1996; McCaffrey, 2001; Tanzi and Arcari, 2001; Gupta, 2004). Whichever of these three schools of thought one subscribes to, it is clear that the attempt at codification based on an inventory and integration of existing state practice influenced state practice itself, and thereby also the development of international law. This model of legal change can be referred to as the incremental model, codification to convention (see Figure 1).

[8] And not on pollution or biodiversity protection.

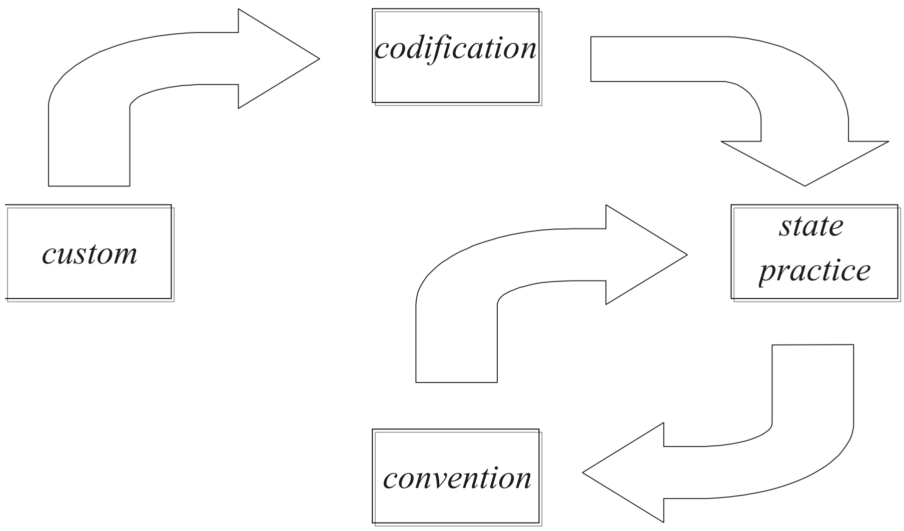

Figure 1. The incremental model of the progressive development of international law.

International Watercourses Convention and industrial transformation

In the case of global water law, the IWC of 1997, when and if it enters into force, will promote industrial transformation through a number of pathways. The Preamble calls on parties to promote the sustainable use of international waters for the protection of present and future generations. The Convention aims at protection, preservation and management of international watercourses (Article 1, IWC, 1997). It promotes the principles of equitable and reasonable utilisation of international watercourses and defines the criteria for such utilisation (Article 5, and 6, IWC, 1997). It obliges countries to not cause significant harm to others, and introduces the principle of compensation for harm caused (Article 7, IWC, 1997). It includes the tools of prior informed consent, and in particular calls on states to prepare water quality objectives and criteria, establish techniques and practices to abate pollution and to establish lists of substances to be prohibited, limited, investigated or monitored (Articles 11-19 and 20-23, IWC, 1997). It also asks countries to provide access to domestic courts to all those negatively affected; in other words to not discriminate between people on the basis of their nationality (see Article 32, IWC, 1997). Finally, it provides for the settlement of disputes (Article 33, IWC, 1997). In other words, international law provides the framework to promote industrial transformation with a view to reducing conflicts over water quality and quantity. The actual achievement of transformation, however, depends on the willingness of countries to ratify the agreement and/or to implement the obligations in the treaty.

The above history is much more complex than in the stylised version presented here. The point I am trying to make is that different countries have developed different legal principles. Codification attempts to unify these principles and thus paves the way for the adoption of a future agreement that specifies, *inter alia*, the principles and instruments that countries must observe in order to meet a specific goal. At the same time, this model should not be seen as a linear process but more as an iterative process in which, as new problems emerge, new types of solutions will be developed by different countries which may then be codified and so on. Since this approach is gradual and based on existing state practice, there is a strong domestic basis for actually implementing the law and, hence, the compliance-pull is high.

Law of sustainable development

A good example of a 'soft law' that might evolve into hard law along the lines of the incremental model is the evolving law on sustainable development. This story begins with the articulation of the principle of sustainable development by the Brundtland Commission in 1987 (WCED, 1987). E.B. Weiss (1989) subsequently wrote a treatise on the content of this principle and the rights of future generations. In the early 1990s, there was increasing global consensus, at least at a rhetorical level, on the need for the global community to focus on sustainable development. While some argue that this is just the emperor's new clothes, *i.e.* the concept is diffuse, vague, self-referential and insubstantial (McCloskey, 1999; Klabbers, 1999; Gabćikovo-Nagymaros judgement, 1997; Lowe, 1999; Pallemaerts, 1993), others believe that it is just as important as other catch-all concepts such as democracy and justice (see also the Separate Opinion of Vice-President Weeramantry in the Gabćikovo-Nagymaros judgement, at p. 88; Dupuy, 1997; Pieratti, 2000; Clark, 2001; Sands, 1998). While some see sustainable development as an end goal, others see it as a procedural issue that guarantees the ability of societies to continue to develop and transform their industries and their societies.

There are two schools of thought on the principle of sustainable development. For one school of thought, the principle is a singular concept as represented in the text adopted in the Climate Change Convention (FCCC, 1992) and the 1992 Biodiversity Convention. For others, the principle itself represents a number of other principles adopted initially in the Annex to the Brundtland Report (WCED, 1987) and the Rio Declaration on Environment and Development (1992). Hence, the ILA attempted to codify the content of this principle. In 2002, the ILA drafted the New Delhi Declaration of Principles of International Law Relating to Sustainable Development. These principles include:

– The duty of states to ensure sustainable use of natural resources;
– The principle of equity, and the eradication of poverty;
– The principle of common but differentiated responsibilities;
– The principle of the precautionary approach to human health, natural resources and ecosystems;
– The principle of public participation and access to information and justice;
– The principle of good governance; and
– The principle of integration and interrelationship, in particular in relation to human rights and social, economic and environmental objectives.

As mentioned earlier, the ILA documents are simply the work of international jurists. They have no formal legal standing and therefore, at best, have only the status of 'soft' law. Having said that, one may also argue that the law of sustainable development might be in the second stage of the evolutionary phase of the incremental model elaborated above. I argued that international water law developed through custom, then codification, then influence on state practice, and then the adoption of the UN Convention on the Law of the Non-Navigable Uses of International Watercourses, which is expected to influence state practice and, in turn, custom. By extrapolation of this argument, one could say that the latest attempt at codification of the principles of sustainable development by the ILA may gradually influence the work of jurists and state practice. As time goes on, the use of these principles may become habitual and may possibly enter the realm of international treaty law, and then even become international customary law. Once they become customary law, they may give rise to obligations *erga omnes,* or to the development of a new constitutional law for the global community.

The law of sustainable development and industrial transformation

The emerging law of sustainable development will gradually promote industrial transformation through the principles of sustainable use and the precautionary principle. The sustainable use principle reiterates that states have the sovereign responsibility to use their own resources but not at the cost of causing significant damage to other states or areas outside their jurisdiction. The ILA Declaration argues, further, that states have a duty to manage natural resources in a rational, sustainable and safe way '…with particular regard to indigenous peoples, and to the conservation and sustainable use of natural resources and the protection of the environment, including ecosystems.' States must take into account the needs of future generations in determining the rate of use of natural resources. All relevant actors (including states, industrial concerns and other components of civil society) are under a duty to avoid wasteful use of natural resources and promote waste minimisation policies. This principle implicitly tries to take cognisance of the need for closing substance cycles, dematerialisation and the problem of dissipating pollution.

In relation to the precautionary principle, the ILA Declaration argues that a precautionary approach is central to sustainable development, that such an approach includes accountability for harm, planning based on, *inter alia*, environmental impact assessments, and an appropriate burden of proof. Such measures should be based on the latest science and developed through transparent structures and judicial review, and not result in economic protectionism. Thus, this new law endorses the precautionary approach but provides some methodological constraints to ensure that it does not lead to non-legitimate law. It does not, however, directly prescribe the technologies that need to be adopted by a society. What it does do is provide the procedural and substantive constraints within which societies should develop in the future.

3. STRUCTURAL MODEL OF LAW MAKING

The second model of legal evolution is the one that can be derived from an observation of the development of the climate change treaties. The scientific information provided by the first and second World Climate Conferences in 1979 and 1990 put climate change on the global political agenda. The complexity of the science led to the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988, entrusted with the responsibility of assessing the available science on climate change at five-yearly intervals. In 1990, the United Nations General Assembly established the Intergovernmental Negotiating Committee to negotiate an international agreement on climate change. Over the years, there has been a close and formal relationship between the negotiating arena and the scientific arena. Hence, the climate change negotiations are influenced considerably by the scientific results and the policy recommendations of the IPCC, although these recommendations are subject to intense political bargaining (Gupta, 1997; 2001a). New instruments and new institutions are being developed as a consequence (Faure *et al.*, 2003), but these instruments, such as joint implementation and emission trading, do not reflect state practice as of yet. Instead, they are based on economic theories and some limited domestic experience, and then these ideas are transferred to the international arena. By including such instruments in international agreements, climate change treaties will encourage state practice through the process of prescription in law, the requirement of reporting and monitoring, and through non-compliance procedures. The adoption of these instruments, however, has been fairly rapid and one may argue that they did not go through a slow evolutionary process.[9]

Until December 1997, one could have argued that the process was steadily moving forward, creating new legal norms, incentives and disincentives for states and actors within states. However, the decision of the US in 2001 not to ratify the 1997 Kyoto Protocol to the United Nations Framework Convention on Climate Change has affected the political will of other countries. After considerable delay Russia has finally ratified the Kyoto Protocol, and it will enter into force in February 2005. There is also clear evidence of continued, although less enthusiastic, decision-making at the annual Conference of the Parties.[10] At the same time, the US remains a party to the 1992 climate convention, and is bound by the law of treaties not to take any steps that counter the spirit of the climate change convention.

Hence, even though some of the key countries have not agreed to the Kyoto Protocol, there is, relatively speaking, a rapidly developing global consensus on the problem of climate change, leading to new developments in international law and changes in state practice as countries are developing national laws and policies to implement the climate change convention. This consensus could lead to a major global transformation towards sustainability by altering the incentive structures within countries. This pathway of law-making could be referred to as the *structural model of the progressive development of international law* (see Figure 2), since the new law does not reflect existing state practice or custom but is inspiring new state practice and custom to reflect the new scientific evidence and political culture. As a result of the new state practice, new norms, rights, responsibilities and penalties are generated within society that lead to new domestic transformations, including a transition to low greenhouse gas-emitting energy technologies. Scientific analysis of the results of these

9 One can argue that the structural model of law making is also reflected in the history of how the United Nations Economic Comission for Europe (UNECE) Long Range Transboundary Air Pollution Regime developed and the international regime in relation to the depletion of the ozone layer (See Gupta 2001).

10 On the other hand, it is also becoming increasingly clear to the US administration that hegemonic approaches are inadequate for nation building and peacekeeping activities. The recent challenges in Iraq and Afghanistan, not to mention Liberia, have led the US administration to re-emphasise the importance of the UN and multilateral diplomacy. This new outlook might bring the US back into the climate change negotiations.

transformations then leads to new recommendations for negotiations, which then influences treaty outcomes (See Figure 2).

Hey (2001; *cf*. Moomaw, 2001) argues that the way the climate change regime, with its complex array of instruments, is developing, shows that a new administrative law is in the making. The Conference of the Parties is regularly engaged in annually developing policies and measures that countries need to implement. Hey argues, however, that there is no credible administrative agency comparable to the domestic administrations of the developed countries that can actually and effectively implement this new form of administrative law. Brunnée (2002) puts it slightly differently. She argues that only two treaties in the climate change regime are international law by virtue of adoption and subsequent ratification and entry into force. In the climate regime, however, the almost continuous process of meetings leading to annual decisions of the Conference of the Parties, which do not require formal state consent through ratification procedures, shows that states are now in the process of 'interactional' law-making, or law-making by interaction. Gupta (1997; 2001b) argues that this continuous process of law making is something the developing and other countries are not equipped to deal with and, as such, it leads to serious questions regarding the legitimacy of the law-making process. This new development in law is being stimulated by continuous scientific developments in the field and the pressure brought to bear by international civil society.

What is significant about interactional law making? The answer is that in modern environmental problems we are moving away from traditional methods of law making. We are moving towards a continuous and creative process of law making that allows for the rapid inclusion of new scientific and policy ideas, albeit when these are developed and found acceptable by the more influential nations. This does not imply that the international regime actually has the administrative structure to effectively implement these new ideas, nor does it imply that all countries will be in a position to implement these concepts (developing countries especially).

Nevertheless, the argument is that the current climate change regime contributes to the process of industrial transformation through its use of principles (Article 3, FCCC), its quantitative targets for developed countries (Article 3 KP), the financial mechanisms (Articles 6, 12 and 17), and the capacity building, technology transfer and non-compliance procedures in the Marrakesh Agreements of 2001. At the same time, it would be wise to say that no transformation will take place if the Protocol does not enter into force and if countries do not in good faith begin to implement it.

While the above section has focused on one exogenous factor influencing law making, *i.e.* the role of science in influencing law, there are other exogenous factors. These include the role of non-state actors in influencing the adoption of principles and instruments in international treaties. For example, non-state actors were the critical factor driving the adoption of the Rome Treaty on the International Criminal Court. NGOs were also the driving force behind the adoption of the Basel Convention on the Transboundary Movement of Hazardous Wastes and their Disposal. Business and industry has shaped many of the agreements launched by the International Maritime Organisation.

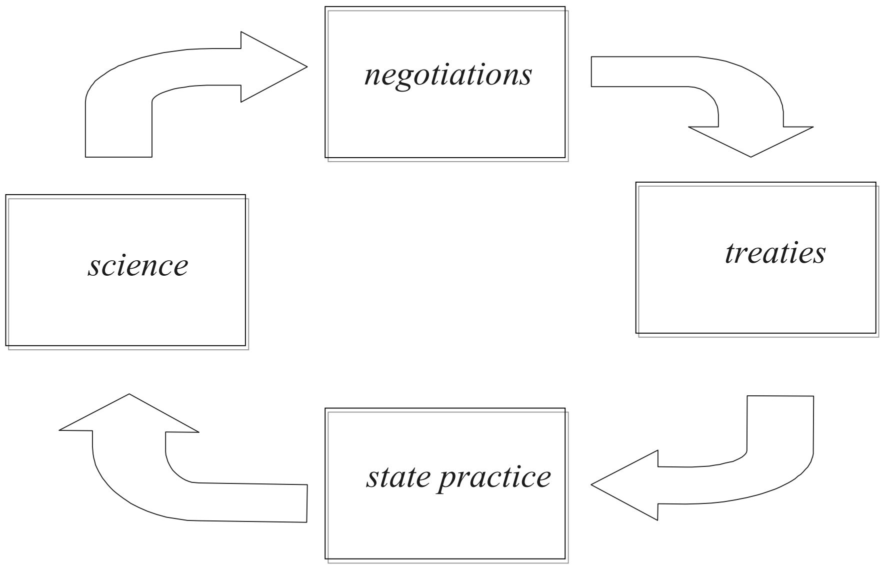

Figure 2. The structural model of the progressive development of international law

4. REGULATORY COMPETITION AND LAW: INTERNATIONAL ECONOMIC LAW

Thus far we have seen two models, one where differing state practice is codified, leading to a gradual harmonisation of law, and one where external stimuli led to the adoption of solutions by negotiators which can then become hard law. In the third model, one that is often reflected on in international economic law, we look at regulatory competition among countries, *i.e.* countries adopt law (including environmental law) to improve their comparative advantages in attracting foreign investors. This contrasts with the above two models in that they strive towards harmonisation of international regulation. Harmonisation is driven by the desire to eliminate free-riders and level the playing field; in other words, to ensure that the same rules are applicable everywhere.

In contrast, in the regulatory competition model, it is emphasised that different countries use different policy approaches to solve their perceived problems. This is because of the contextual nature of domestic politics. However, if a country wishes to promote strong environmental and social protection through the implementation of a strict set of standards, it may feel frustrated if industry then decides to move to other countries where the rules are less strict as this will have an impact on the national economy as well as the environment (*cf.* Esty and Geradin (eds.), 2001; Majone, 2001).

The issue of how regulatory competition influences transitions in society is very important for international economic law, especially in the context of trade liberalisation and economic integration. The regulatory competition school recognises that different legal frameworks and political systems co-exist. While, on the one hand, the co-existence implies that each country experiments with its own incentive framework, the big challenge from an environmental perspective is that this can lead to a race to the bottom. On the other hand, regulatory coordination based on rules of consensus may lead to the lowest common standards being adopted and, hence, may not be a much better option (Sand, 1990).

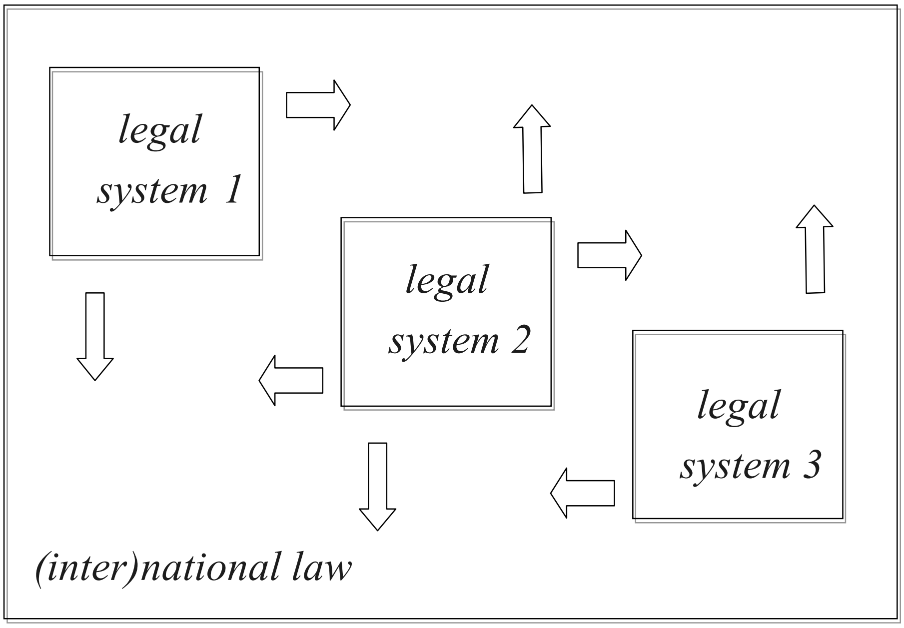

Figure 3. The regulatory competition model of the progressive development of international law

Some optimists argue that since regulatory coordination is inadequate, regulatory competition may lead governments to continuously revise their domestic laws to provide better incentives than others to promote national welfare. This leads to a 'race to the top,' *i.e.* competition to change the behaviour of social actors in a way that improves national welfare. Since empirical research shows that this does not always happen, a new generation of scholars (*cf.* Esty and Gerdin (eds.), 2001) has been focusing on the conditions under which regulatory competition can enhance welfare in countries (see Figure 3).

5. CONCLUSIONS

The above sections have shown that empirical observations of how international law develops reflect three ideal typical models of the progressive development of international law. Where there is a long history of dealing with a specific problem, countries have already developed national legal frameworks for dealing with these problems. Here, attempts at dealing with the transboundary nature of these problems have led to harmonisation of policies through an incremental process, moving typically from diverging national customs to codification through state practice, to treaty negotiation, and, finally, to customary international law development.

In other situations where countries have to deal with new problems, epistemic and/or NGO communities may be in a position to develop new ideas that are then introduced into the international legal arena, leading to the structural evolution of law. In the third situation, where economic welfare is the driving factor, countries decide not to over-regulate the field at the international level because of the perceived negative economic implications for the domestic context, and to instead use national regulatory frameworks to promote national goals.

All three models may conditionally promote industrial transformation. The first model is a slow process based heavily on the compliance-pull features of international law (namely: *pacta sunt servanda*, state consent and good faith). Compliance-pull is seen by many as the most important reason why states (and individuals) implement the law. 'It is thus the perception that makes the rule law, not the guarantee of sanction. Similarly, we assert that a sanction is not necessary to make *international* legal rules binding. It is enough that states regard the rules as binding and, accordingly, believe that a sanction would be appropriate for a violation of such rules.' (Arend, 1996: 290) The incentive for industry to change behaviour comes endogenously from within the perceived needs and choices of the domestic society.

The second model is based heavily on the compliance-push features of international law (namely, monitoring, reporting, expert review, enforcement, non-compliance procedures, judicial access, *etc*.) combined with some new forms of compliance-pull features such as financial mechanisms that provide incentives. This model can promote industrial transformation relatively fast. The third model of law embodies contradictory tendencies and can have a strong or low technology push effect. Unlike the first two models, which are driven by environmental (or other social and scientific) goals, the third model is driven by economic motives.

An understanding of the way the law develops can help those who wish to identify possible points of intervention and design incentives for industrial transformation to know how they can influence the international law-making process. I would argue that the three ways to influence the development of international law, is to either promote the codification of existing principles, or promote a close and formal link to scientific bodies and/or non-state actors or through conditional regulatory competition so that a race to the top can be promoted. The case study of the evolving law of sustainable development demonstrates an instrumental use of legal tools to promote the codification of principles that can provide incentives for sustainable development.

Let me end by making few observations. First, law provides the framework within which international society functions. In other words, it guarantees certain constitutional protections and the rule of law. In this sense it is the systemic foundation of society. This aspect of law has constraining features as well, however, in that it limits the speed of change to that which is constitutionally acceptable or in line with the rule of law. Having said that, one may argue that the lack of a clear constitution and legal superstructure that goes beyond the UN Charter implies that there are fewer constitutional guarantees at a global or international level.

Second, specific laws influence state and human behaviour through their normative force (Dijk, 1987) and their articulation of principles, incentives, rights and responsibilities, and penalties. While there is a tendency in other disciplines to focus exclusively on incentives (carrots) and penalties (sticks), it is important to remember that the normative force of law is seen in the legal literature as having considerable influence on nations. This is referred to in the international relations literature as the ‘logic of appropriateness’. The mechanisms of law making try to ensure that international law has a strong compliance-pull and compliance-push.

Third, general principles of law are proactive in the limited sense that they provide judicial remedies for possible future wrongs through, for example, the no-harm principle and liability at the international level. In relation to industrial transformation, this implies that producers are under notice that, if they cause harm through their production process, they may be held liable under the law. This provides the incentive for taking preventive and precautionary action. Having said that, it must be acknowledged that cases in relation to transboundary harm have been fairly limited. Not much empirical evidence exists to explain why this might be the case, but there is speculation in the literature that this is because countries are afraid to develop legal precedents that may work against their interests in a different environmental issue. Another reason is that the cause-effect chain is not very clear in many international environmental problems.

Fourth, law tends to be reactive to problems. It is thus a limiting factor in that it limits transformation to the boundaries of legality, or what is legally possible. On the other hand, law can theoretically also be a forcing factor in that it can, on occasion, force societies to change direction through, for example, technology-forcing standards. In such a situation, a society can use the law to promote change. At the same time, through new interpretations by the judicial community and normative communities, the implications of the rules will change.

Fifth, although this paper has not gone into the impacts of bilateral investment treaties, private international law and trade law, there are rapid developments taking place in these arenas, which may also have a major influence on how countries and domestic actors within them behave. For example, while World Trade Organisation (WTO) / The General Agreement on Tariffs and Trade (GATT) rules do not at present allow countries to differentiate between imports from other countries on the basis of the production processes, this is a hotly debated point in those discussions. At the same time, national and international initiatives to promote labelling schemes that induce environment- and socially-friendly behaviour by consumers may have an impact on production processes in other countries (Campins and Gupta, 2002).

Finally, international legal science complements the development of transformation science, as developed within the IHDP-IT programme, even though it may not necessarily use the same vocabulary (*e.g*. de-materialisation *vs.* sustainable use), focus on the same issues (*e.g*. incentives *vs.* norms, compliance-pull and push), or use the same tools (*e.g*. life-cycle analysis *vs.* environment impact assessment). International legal science is essentially positivist (prescriptive) and normative (focusing on justice and economic efficiency). But there needs to be much more empirical work to explain the changing dynamics in the legal world which calls for closer cooperation and collaboration between legal scholars and social scientists. At the same time, an institutional research agenda is being developed internationally, leading to a merger of some approaches within the legal, international relations and economics fields, although the approaches remain none the less distinct. This is taking place under the auspices of the Institutional Dimensions of Global Environmental Change (IDGEC) Programme of the IHDP. This programme focuses attention on three areas of research, which institutions are responsible for the environmental problem, why do some institutions function better than others, and, finally, how can one design a better institutional framework (IDGEC, 1999) to promote industrial and social transformation in the direction of sustainable development? The big gap in transformation research from a legal perspective is that, although new legal tools are being developed to deal with new legal problems, there is limited theory-forming in the area of international environmental law, limited empirical research on international environmental law issues, and limited analysis of the role of norms in shaping international agreements.

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Chapter 5

CONTRIBUTIONS TO TRANSFORMATION RESEARCH FROM POLITICAL SCIENCE

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Abstract: This chapter analyses the extent to which recent trends in governance are likely to contribute to an encompassing industrial transformation. These trends are (1) the emergence and involvement of non-governmental actors in the policy process, (2) the development and introduction of new instruments, and (3) the growing importance of the international and the subnational level of policy-making.

Key words: governance, stakeholder participation, international regime, instruments and strategies of environmental policies.

1. INTRODUCTION

The study of political science is concerned with the emergence and effects of policies and political systems at local, regional, national and international levels. Each national or international political process involves many different actors, ranging from national governments, intergovernmental organisations and local authorities, to private actors such as business associations, NGOs, scientific networks and the media, all acting

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in a given institutional framework. In that context, political science in particular analyses:

- The institutional framework (polity), that is, the set of formal and informal rules that have evolved to govern the activities of the actors at different levels from local to international;
- The interest, power and behaviour of the various actors in the political process (politics); and
- The actual policies, their objectives, related strategies and instruments that are chosen in order to regulate public affairs (policy).

A key interest is why a certain policy has been chosen and what effects it has in motivating or constraining the behaviour of public and private actors.

The study of environmental policies has gained attention in western industrialised countries since the 1970s. Academic work in the field has been conducted to analyse the determinants of unsustainable economies. Particular attention has been given to issues such as the external effects of production, internalisation of external costs, consumer preferences that do not sufficiently consider the environmental burden of consumption, and the lack of market signals for more sustainable production.

In response, ‘the state’ and ‘the government’ have frequently been called on to correct these market failures and solve the pressing problems of environmental degradation. However, the role and action of governmental actors is limited, as public policies are the result of complex bargaining processes. Environmental policies meet strong resistance not only from the target groups that are potentially affected by additional costs but from the various governmental actors as well. The manufacturing industries, for example, contribute to economic prosperity, tax revenues and employment. For that reason, any (environmental) measures that potentially affect the economic performance of industries are likely to meet with resistance not only from the industries themselves, but also from political actors that represent the interests of these industries, such as business associations and unions, or the regional governments of areas in which the industries are located.

Furthermore, it is not only the adoption of policies that is disputed, but also the implementation and monitoring of regulations, which often require substantial resources. It is especially their allocation that is frequently discussed at some length by governmental actors. For this reason, environmental policies had to build up considerable capacities in the past to become effective in the political process. These capacities encompass administrative competency, the relative power of environmental authorities inside the government, the knowledge basis to monitor environmental changes and to develop technologies to solve them, and the ability of environmental organisations to participate effectively in the political process (Jänicke and Weidner, 1997; Knill, 1999; Peters, 1996).

Alongside the development of these capacities, a modernisation of environmental policies took place in many countries. In particular, three major trends from single government to governance can be identified in the environmental policy process that emerged as a result of this modernisation movement. The trends can be depicted as follows (Heritier, 2002; Hey, Jänicke *et al.* 2003; Biermann, forthcoming, on global governance):

– *Emergence of new levels of governance*. Due to globalisation processes and the emergence of global governance, the importance of national policy-making declined over the last few years, while other levels, both international and sub-national, gained added importance;
– *Emergence of new actors*. Current political processes often call for more democracy and new forms of participation in order to improve the legitimacy of decision-making. As a manifestation of this process, the average spectrum of actors involved in policy-making broadened significantly, contributing to a shift towards non-state actors and to a decline in authority for central governments.
– *Emergence of new instruments*. The involvement of a greater number of stakeholders, as well as the emergence of new governance forms, called for broadening the existing range of policy instruments, leading away from command-and-control approaches towards the implementation of economic instruments and new flexible, integrated, co-operative policy measures with shared responsibilities for the government and target groups.

How far are these trends likely to contribute to a transformation of societies towards sustainability? And how can political science contribute to building up the knowledge base that will help societies to develop further without jeopardising the quality of life-support systems? This chapter analyses the three trends that became manifest as a result of the modernisation of environmental policies, as the insights gathered from this analysis may be of great use to the study of societal transformation towards a more sustainable future.

We will first look at the increasing importance of the international level in environmental policy-making (Section 2). Section 3 expresses our views on the potential contributions of civil society to the political strategies aiming at a transformation of unsustainable production and consumption patterns. In Section 4 we analyse how far political strategies and instruments have been affected by the depicted trends in governance. These are: end-of-pipe approaches, policies to stimulate environmental innovations, and green industrial policies. Section 5 closes with a discussion of whether the systemic approach of industrial transformation research is likely to gain from these trends.

2. THE INTERNATIONAL DIMENSION OF INDUSTRIAL TRANSFORMATION

In a world of increasing ecological and economic globalisation, with its high degree of political and economic integration in many regions, the quest for industrial transformation can no longer be seen exclusively from the framework of the nation-state and national policies. Industrial transformation processes in one country, or in a group of countries, will not suffice to address today's inherently global environmental problems. Of course, many environmentally friendly innovations will diffuse around the globe by the mere force of the market. Other innovations, however, might face more problems, and the quest for worldwide industrial transformation thus raises the question of how decision-makers can best influence and steer these processes.

Within political science, two communities of researchers have been involved in the analysis of this problem (Biermann, 2002; Biermann and Dingwerth, 2004): on the one hand, political scientists who study international relations (IR) investigate options to build strong and effective international institutions and to establish new forms of global governance that further sustainable development (Young, 1990 and 1997). On the other hand, researchers in the tradition of comparative and national (environmental) politics focus their research on the transnational diffusion of policies and technologies; often finding that managed economic globalisation will foster the diffusion of successful policies and more efficient technologies between nation-states largely without the intervention of international institutions. The following section discusses the research of the former tradition and the study of the spread of environmental policies over countries.

International institutions: solution to the global environmental crisis?

Political scientists trained in the field of IR have focused their research on international environmental institutions as mechanisms of environmental governance in the global realm. This research programme is embedded in the general IR discourse on states and institutions. Since the mid-1980s, international environmental policy has become a mainstream topic for IR scholars within the analysis of international regimes, as the central meeting ground for different schools in the IR community (Haggard and Simmons, 1987; Hasenclever, Mayer and Rittberger, 1997; Kohler-Koch, 1989; Krasner, 1983; Rittberger, 1995). Theoretical discourse on international environmental policy has followed the cycle of political developments: research focused first on the emergence of international environmental regimes and of the norm-setting process within regimes. Following the enormous growth in the number of international regimes in the 1980s and 1990s, scholars turned their attention to the actual influence these regimes had on policies pursued by nation-states — a debate about 'regime effectiveness' that has produced an impressive amount of literature in recent years (Haas, Keohane, and Levy, 1993; Keohane and Levy, 1996; Miles and Underdal, 2000; Victor, Raustiala and Skolnikoff, 1998; Weiss and Jacobsen, 1998; Bernauer, 1995; Helm and Sprinz, 2000; Sprinz and Helm, 1999; Young, 2001; Zürn, 1998).

The key premise of this literature is that the global environmental crisis requires intergovernmental institutions to constrain the behaviour of nation-states in order to bring about significant transformation. It is argued, often implicitly, that in a world with no intergovernmental institutions and with only nation-states acting independently, the state of the global environment would be significantly worse.

This line of research has provided a number of useful insights into the factors that could make international environmental regimes more influential on individual state action regarding industrial transformation. Some research points to the relevance of regime design. In the case of maritime oil pollution, for example, it has been shown that different international norms and verification procedures have entirely different outcomes on the overall effect of the regime (Mitchell, 1994a; 1994b). Different modes of regime allocation are also likely to influence regime effectiveness, for example in climate policy (Tóth, 1999). Crucial, too, is whether a given regime includes systems for reciprocity and sanctions or rewards, which would require as a first step a credible verification system that assures all actors that their, and others', behaviour is known (Mitchell, 1998). Some scholars, especially those who base their arguments on game theory, have argued in favour of strict sanction systems to punish free-riding nation states. Others see less confrontational approaches as more likely to be effective, since most nation-states do not willingly breach agreements, but rather do so for lack of necessary resources (Chayes and Chayes, 1993; 1995; Wolfrum, 1998). The co-operative approach taken by the parties to the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer (Benedick, 1998) *vis-à-vis* the default of the Russian Federation might serve as an example (Victor, 1996).

Apart from the design of regimes, which could in theory be altered by states in subsequent negotiations, IR research points to a number of additional external factors that might explain variations of success among regimes in achieving transformation processes (Biermann and Dingwerth, 2004). Crucial variables are the structure of problems and issue areas: controlling the phase-out of chemicals for which substitutes are widely available is quite different from halting soil degradation in arid countries through international law. In the case of regional regimes, the characteristics of their members are key factors in explaining cross-regional variations in regime effectiveness. Finally, the overall context matters, that is the general economic situation or non-environmental political concerns that might explain the policy outcome, for example, Soviet policies in the regime on long-range transboundary air pollution in Europe (Levy, 1993).

Notwithstanding the vast amount of literature on the influence that intergovernmental regimes have on national environmental policies, the IR community still lacks a generally accepted definition of institutional effectiveness, which has given rise to a number of conceptual papers on this elusive dependent variable (see for example Bernauer, 1995; Helm and Sprinz, 2000; Keohane, 1996; Underdal, 2000; Young, 2001). Concepts of regime effectiveness or success range from assessing the *output* of the regime in terms of legal promulgations or policies enacted (an approach typical for much legal writing) and *behavioural change* amongst political actors (outcome), to an appraisal of the eventual *environmental impact*, that is, whether changes in state behaviour have actually improved the state of the ecosphere (Cioppa and Bruyninckx, 2000).

The role of the nation-state takes an entirely new turn with the emergence of supranational organisations for regional economic, political and social integration. The European Union is a unique case in this respect because of its deep integration, but it is likely that other regional integration organisations and agreements, such as the North American Free Trade Agreement, will evolve in a similar direction at least regarding environmental policies. The European Union provides an interesting case in both its external and internal influences. Externally, it is the main institution influencing the national environmental policies of Eastern European states wanting to accede to the Union over the next years. Internally, the European Union is a special case on the influence of international institutions on national policy, as well as of the horizontal influence of other nations (Jachtenfuchs and Strübel, 1992; Andersen and Liefferink, 1997; Jordan and Lenschow, 2000; Knill and Lenschow, 2000). The core question here is whether increasing European integration will eventually result in some form of convergence of national policies on industrial transformation over time.

The debate on the respective influence of intergovernmental institutions versus transnational diffusion on national policies, as well as the new role of non-governmental actors both from the environmental community and from business, has given rise to new theoretical thinking about 'global environmental governance' (further references in *e.g.* Biermann, forthcoming). This includes governance arrangements between public and private actors as well as governance mechanisms that span different levels of decision-making, for example in regimes negotiated at the global level that leave significant decision-making power with nation-states by merely agreeing on international standards for information-sharing to enable governments to take better and more informed decisions, such as the 2000 Cartagena Protocol on Biosafety (Gupta, 2000a and 2000b).

The transnational diffusion of policies and technologies

These writings of IR scholars rarely relate to findings from experts on (comparative) national industrial transformation policy. Surely domestic factors are accounted for in IR research: much recent writing on IR attempts to integrate negotiations between state governments with domestic negotiations within states, for example between environmentalists and industry, or between different levels of bureaucracies (for environmental work bridging the divide, see *e.g.* contributions to Hanf and Underdal, 2000). However, first and foremost the literature on international environmental co-operation relates to general IR theories and debates. It is IR theories that are being applied to the study of international environmental co-operation, and it is these IR theories that many students of international environmental co-operation strive to contribute to. Often, studies on international industrial transformation politics draw predominantly on authors from the IR community, but not on those colleagues who are working on the same political problems, for example, climate change, from an entirely different angle: comparative politics and policy analysis.

This disjuncture is the more interesting since many researchers from comparative law and politics, innovation studies, and environmental policy have asserted that the role of the nation-state remains central, and that international institutions in many cases are epiphenomenal. The claim is that the globalisation of national environmental policies, rather than international institutions, has been responsible for the many environmental successes of the last decades (see for instance Conrad, 1998; Jänicke and Jörgens, 1998 and 2000; Jänicke and Weidner, 1997). Contrary to criticisms of globalisation, a number of empirical studies seem to indicate there is evidence for an environmental 'race to the top' rather than a 'race to the bottom.' According to this literature, there is no emigration of industries to 'pollution havens' that others fear will be the outcome of a globalised economy based on competitive nation states (see Vogel, 1995 on the 'race to the top' hypothesis; for an extensive economic discussion, see Althammer *et al.*, 2001).

Despite all critical assumptions, nation-states seem to keep their central role in the international development of environmental policy, both in the model of horizontal diffusion and country-by-country learning, as well as in the model of furthering international regimes (Volkery and Jacob, 2003; with additional references). The policy monitoring of basic environmental policy innovations for the past 30 years reveals lively processes of innovation and diffusion: environmental policy innovations of certain countries do spread either voluntarily from one country to another by learning and adaptation, or they are taken over and further developed by international agreements (Tews *et al.*, 2003; Binder, 2002; Jörgens, 2003). The emergence of many international agreements can be traced back to the initiatives of single countries or groups of countries that also influenced their evolvement without meeting great resistance by other countries (Young, 2002; Underdal 1998).

It cannot be neglected however, that the growing number and the scope of international environmental agreements, international organisations and economic and political globalisation, remain an important factor in the development of policies that are relevant for environmental performance. Besides the growing importance of the international sphere in policy processes, it is often argued that a greater involvement of actors from civil society is indispensable for far-reaching change. The role of civil society will therefore be considered in the following discussion.

3. NEW ACTORS: STAKEHOLDER INVOLVEMENT IN TRANSFORMATION PROCESSES

Industrial transformation focuses on far-reaching approaches in order to reach sustainability. To be effective, these approaches have to focus on systems and systems change, a system being defined as: "a chain of production, distribution, consumption, and disposal activities, including the incentives that shape this system, *i.e.* property, liability and fiscal laws and regulations" (Vellinga and Herb, 1999). A system change denotes a gradual, continuous process of structural change within a society or culture. Such a process connects technology development to mutually-reinforcing parallel economic, institutional, and cultural changes in society (Elzen, 2001). Due to the complexity of this matter, and the various interests that are at stake, this cannot be done by governments alone, but requires the involvement of actors from civil society, such as business companies, environmental and consumer NGOs, and the general public (*cf.* the idea of problem structuring, see Hisschemöller and Hoppe, 2001). This has led to a significant broadening of the average spectrum of actors involved in the policy-making process, which, in turn, has contributed to the decline of authority of central governments. The current political process often calls for more democracy and new forms of participation in order to safeguard the participation of the non-state actors. The analysis of these actors is one of the major activities of political scientists. We will now address the need for proper involvement of stakeholders in transformation processes.

The various actors from civil society are referred to as 'stakeholders.' In simple words, a stakeholder is an individual or a group that has an interest in a certain issue. However, due to the complexity of the issues and interests involved in transformation processes, it may not always be clear what the stakes of each actor are. Different actors may have a different perception, and the stakes may change over time. Furthermore, the group of relevant stakeholders is not necessarily fixed but may change in composition, too. As the transformation process develops, new stakeholders will enter the scene and others will leave.

There are five different reasons for promoting stakeholder involvement in transformation processes (van de Kerkhof, 2004). First, stakeholder involvement may increase *public awareness* and *acceptance* of the need for a system change and of the consequent actions that are required (Kickert *et al.*, 1997). Second, involving stakeholders may lead to *better decisions*, as it can enrich the decision-making process with relevant information (viewpoints, interests, experience) about how to accomplish a system change, which could not have been generated otherwise (Teisman, 2001). Third, stakeholder involvement may increase the *legitimacy* of decisions. Fischer (1990; 2000) argues that, due to the complexity of contemporary problems, society has become increasingly technological in character and the decision-making process has become strongly dependent on the knowledge of scientific experts. At the same time, however, scientific experts have largely separated themselves from society. Moreover, the experience of the past decades reveals that the scientific experts often lack the answers to complex problems. Stakeholder involvement may increase the legitimacy of decision-making, as it enables the stakeholders to engage in deliberation about the decisions that need to be taken by public authorities. Fourth, stakeholder involvement may increase the *accountability* of decision-making, as the stakeholders get an inside view of the decision-making process and they become co-responsible for those decisions and for the actions that need to be taken (Van Kersbergen and Van Waarden, 2001). Fifth, stakeholder involvement may result in *learning*. In that case, government, scientific experts and other stakeholders enter into a dialogue and, by interaction and debate, they learn how to collectively stimulate the transformation process (Van de Kerkhof and Wieczorek, 2003).

Although the involvement of stakeholders from society is important, there are also several factors that may prevent participation from working (Van de Kerkhof, 2004; Berk *et al.*, 1999). One of these factors concerns the involvement of *citizens* in the transformation process. According to some political theorists, such as Schumpeter (1942, referred to in Hisschemöller, 1993), citizens are not sufficiently capable of rational judgement on complex matters that go beyond the experiences of their daily life. Especially in matters that involve values, such as politics and environmental problems, citizens' policy preferences are merely malleable opinions that change with the issues of the day. According to this criticism, citizens are only rational to a limited extent, even when their own interests are at stake. Furthermore, citizens and other stakeholders are most likely to defend their own short-term interests and take a 'free ride' on collective goods. This means that the more stakeholders who want to defend their own interests are involved, the more difficult it will be to develop a strategy for inducing a specific transition. A second, more fundamental, factor that may prevent participation from working relates to the criticism that stakeholder involvement, depending on how it is organised, may threaten the legitimacy of representative democracy. According to this critique, more participation is not intrinsically more democratic, as it may override existing legitimate decision-making processes and undermine the position of parliament (Cooke and Kothari, 2001). A third factor is referred to as the 'participation paradox' (Seley, 1983, referred to in Berk *et al.*, 1999). This means that stakeholder involvement in transformation processes can lead to decisions that reinforce the interests of the already powerful, and at the expense of the interests of the less powerful. In order to participate effectively, one needs power resources that are not equally distributed over the affected population. Power resources include *inter alia* access to relevant information and a voice loud enough to get heard by decision-makers. Weaker interests are in a marginal position, so participation facilities will not be of great help for them. A last factor that may prevent participation from working is the absence of objective selection criteria for stakeholder involvement in designing and deciding on policies for industrial transformation processes. The number of potential stakeholders is very large, so if everyone were allowed to join the process, the debate would never end and decision-making would become impossible. As a result, only a selection of stakeholders can be involved, which raises questions about representativeness.

These critical comments on stakeholder involvement make clear that setting up an interactive process to explore and facilitate a transformation is not easy. However, as mentioned before, we do not regard these criticisms as a categorical rejection of stakeholder involvement, but rather as factors that may prevent participation from working. The criticisms stress the need to carefully think over the question of how to design and implement transformation processes in such a way that the involvement of stakeholders effectively contributes to the identification of research priorities, to the exploration of strategies that are needed to facilitate a transformation, and to the implementation of these strategies.

The next section analyses a number of political strategies that have been used so far in environmental policies, and how the actors from society play a role in these strategies. It concerns end-of-pipe policies, innovation-oriented environmental policies, and green industrial policies.

4. NEW INSTRUMENTS AND STRATEGIES FOR ENVIRONMENTAL POLICIES

Over the years, many different typologies have been proposed for the classification of different approaches towards environmental problems. For instance, Vellinga and Herb (1999) propose the distinction between reactive, receptive, constructive and pro-active approaches. Jänicke (1984) developed a comparable typology that distinguishes measures aiming at repair, end-of-pipe, ecological modernisation, or structural change. These typologies distinguish policy measures, actors involved, and the way in which corporations and industry respond to environmental policies. Initially, beginning in the 1960s, command and control policies of governments were met by end-of-pipe technologies. The shortcomings of these approaches, both regarding environmental effectiveness as well as economic efficiency, are well known. In order to stimulate the development and adoption of more innovative environmental technologies, more flexible and participatory modes of governance were introduced. A closer analysis of these approaches may provide some guidelines and useful insights into the design of new strategies and instruments that enable society to decouple economic growth from the environmental burdens that such growth seems to entail.

This section analyses the end-of-pipe approaches and other strategies for environmental innovations, such as green industrial policies, to assess the degree of political challenge they pose and the scope of change that they may potentially bring about. We analyse how far new actors become involved, and new instruments are applied.

End-of-pipe policies

Initially, environmental policies in industrialised countries imposed mainly clean-up operations and end-of-pipe approaches to reduce emissions. This leaves firms' core activities unchanged. As a result, resistance by firms is not that severe, and the policy is easier to adopt and implement. End-of-pipe policies rely to a large degree on command-and-control measures that are imposed by government actors, among which environmental agencies are most important. Other departments may oppose environmental standards because they safeguard the economic interests of target groups. Environmental NGOs are less important; they may act as watchdogs or as proponents of stricter standards. Other levels of government than the national level are hardly important. For some environmental pollutants with long-range dispersal, international regimes have been set up. These regimes contribute to stricter national policies than in situations with only unilateral regulation. The sub-national level plays a modest role in the implementation of the regulation and monitoring the compliance. In this mode of regulation, the nation-state remains the most important driver.

End-of-pipe measures require monitoring and controlling the compliance of regulations. Therefore, the costs of regulation can be remarkable, and administrative capacities have to be built up. Empirically, the costs for the target group are almost negligible, apart from a few branches and enterprises for which standards leading to considerable requirements for investment were imposed. These kinds of policies have several disadvantages (*c.f.* Binder 1999). A major one is that end-of-pipe approaches are shortsighted and, therefore, may lead to lock-in situations, since they do not sufficiently take account of expectations of environmental demands becoming stricter in the future. So, although in the short run end-of-pipe solutions may be economically efficient, they may lead to higher costs in the long-term perspective. In addition, and consequently, there will be a lag in taking measures.

Another alleged problem of end-of-pipe solutions is that they tend to shift problems, *e.g.* the installation of filters to tackle air pollution problems leads to an accruement of hazardous waste. A more fundamental problem is that end-of-pipe solutions are not suited to environmental problems such as climate change and land degradation. End-of-pipe technologies are the initial answer to command-and-control policies of governments. In this game, there is little room for participation and multi-level governance approaches. So in general, this policy model has become obsolete to some extent.

Innovation-oriented environmental policies

End-of-pipe technologies are, by definition, not sufficient to contribute to sustainability. Technological environmental innovations are expected to solve at least some of the shortcomings of end-of-pipe technologies. The scope of policies that contribute to such a modernisation is much broader. Such policies challenge the core processes and the products of enterprises. Unlike the case of end-of-pipe regulations, environmental requirements cannot be met by adding a division of specialists. Rather than that, innovations require R&D efforts by the enterprises, which often interfere with their central operations. So far, this lack of investment in the R&D of environmental innovations is because of the double externality of the profit that can be achieved by environmental innovations. First, as for any R&D activities, there are spill-over effects; second, the improvements in environmental quality are a public good and thus the level of investments in R&D is lower than the economic optimum (Carraro, 2000; Rennings, 2000). Therefore, as underlined by empirical studies on environmental innovations, the innovation and diffusion of environmental technologies largely depend on public regulation (Weale, 1992; Klemmer *et al.*, 1999; Jänicke, *et al.*, 2000). These studies, based on the evaluation of innovation processes, have also allowed for making some policy recommendations. They encompass the 'multi-impulse hypotheses' (Jänicke *et al.* 2000), 'design criteria' for environmental policies (Norberg-Bohm, 1999), or proposals for a 'strategic niche management' (Kemp *et al.*, 1998).

Regarding policy instruments, any environmental innovation can hardly be explained by a single policy instrument (Wallace, 1995). Because of the complex nature of innovation, the influence of a specific regulation is extremely difficult to identify (Rothwell, 1992). The set of instruments for innovation-oriented approaches is therefore much broader than the command-and-control regulations imposed for the end-of-pipe technologies. Command-and-control regulations still play a role in respect of technology forcing, when a certain standard is set as obligatory for a future date. Most scholars, however, call for economic, persuasive or self-regulatory instruments in order to stimulate the successful development and diffusion of environmental innovations, as these instruments leave some room for the target group to manoeuvre. The wide range of instruments that are applied for enacting and enforcing environmental innovation policies requires involvement of the environmental ministry but also other governmental agencies, such as, for example, R&D/innovation bodies and the responsible sectoral ministries (agriculture, industry, transport, energy, *etc*.).

Environmental NGOs also play a more significant role compared with command-and-control regulations by contributing to the development of objectives, the communication of problems, and monitoring the achievement of targets, thereby partially overtaking governmental functions. Furthermore, persuasive policy instruments are available to private actors as well; NGOs initiate information campaigns or develop environmental labels. The number of private-private alliances between NGOs and firms that have the potential to influence environmental policy-making to a large degree is growing considerably (Jacob and Jörgens, 2001).

Still, it is the level of the nation-state that is most important for innovation-oriented approaches, although this is challenged by the processes of Europeanisation and globalisation. It remains largely the nation-state that frames the national innovation systems and that is able and legitimated to enact policies that direct innovation activities towards greening of technologies (Hübner and Nill, 2001).

Recent studies on the emergence of environmental innovations itself have also broadened the perspective by looking beyond single innovators and single-policy measures for the entire innovation system (see, for example, Kemp *et al.*, 2000; Hollingsworth, 2000). Innovation is seen here not merely as a deliberate choice at the level of the firm, but as a set of complex interactions between firms and their environment. Innovations occur in, and are shaped by, the network of inter-firm relations, as well as the social, cultural, institutional and organisational context. The variation among different countries and regions, and their capacity for innovation, has been conceptualised as '(national) innovation systems' in which innovative firms are an integral part of a network of actors that includes other firms, research institutes and universities (see, *e.g.* OECD, 1999). The notion of national innovation systems is not (yet) a consistent theory but, rather, it tries to combine a wide range of influencing factors that could explain national and regional differences in innovation activities.

Strategies for the stimulation of innovations vary regarding the degree of difficulty and depending on the scope of the required change. If technologies are available, and if they demonstrate their technical and economic feasibility, the task is primarily to support their diffusion. Resistance by the target group can be expected only if the affected industries prefer to use their previous technologies for a longer period of time. If the required technologies are not yet on the market, or can only be obtained at high costs, there are two possibilities. First, regulators may choose to set standards for a future date (technology forcing), which is likely to evoke resistance by the target group or other governmental agencies. Second, regulators may choose to subsidise the development and marketing of the environmental innovations, which may require considerable financial resources. It can be shown empirically that environmental policies more often aim at supporting the diffusion of existing technologies than enforcing the development of new technologies (Conrad, 1998; Jacob, 1999). Policies will also be more easily adopted if there are international examples for such policy measures. The examples of pioneering countries are often used to legitimise planned policies.

Strategies that aim at stimulating environmental innovations have considerable potential for environmental relief, but clearly also have severe shortcomings. For example, technical solutions are not available for urgent global environmental problems, such as land use change or the loss of biodiversity. Yet environmental problems are increasingly caused by actors lacking the capacity to develop innovations, such as small enterprises or private households. Industries, however, that use only a few, large-scale and capital-intensive technologies such as steel or energy production, have also often set up powerful political resistance to requirements regarding the modernisation of their facilities or products. This is especially the case for those large industries whose technologies have long investment cycles. Industry that lacks the capacity to innovate might also try to find new market opportunities for harmful substances. Finally, the effects of ecological modernisation are often immediately offset by rising demands and hence new emissions (rebound effect).

To conclude, innovation-oriented strategies bear many features of the above-mentioned trends of governance: new instruments are experimented with, new actors gain importance, and, to a lesser degree, other levels of policy-making than the nation state become relevant. Yet it remains largely the task of national governmental actors to adopt and enforce such measures.

Green industrial policies

Given the shortcomings of innovation-oriented policies regarding certain environmental problems, there is a call for more far-reaching approaches. Green industrial policy provides such an approach; it is an economic policy that aims at reducing the environmental burden of industrial production by reducing the size of the most polluting sectors (inter-sectoral structural change). Green industrial policy is based on the observation that the main share of the environmental burden, in industrialised countries, is caused by a few industrial sectors, in particular the extraction of natural resources, energy production, production of metals, production of mineral products, the chemical industry and the production of pulp and paper (Binder, 2001). Unlike innovation-oriented environmental policies that aim at identifying win-win opportunities in the long term, stimulating marketable and competitive technologies at the expense of polluting industries generates losers.

To be effective, a green industrial policy needs to have a long-term focus and to be closely interlinked with other policy domains, notably economic policy and regional planning. In general, there should also be some mechanism to deal with, and possibly even to compensate for, the losers of structural change, which will require close links to social and welfare policies (Jänicke *et al.*, 1997; Binder *et al.*, 2001).

Examples of such industrial policies are: the phase-out of Japan's primary production of aluminium; the minimisation of oil consumption after the explosion of oil prices in the early 1970s in many western industrialised countries; and the phase-out of nuclear power in Germany. Except for this last, these policies were hardly driven by environmental concerns. In other cases, the decline of highly polluting industries, such as the phase-out of coal mining in the Netherlands and crude steel production in Luxembourg, these developments were mainly driven by autonomous economic forces. In some cases, however, related industrial (*e.g*. employment) policies even ran against economic developments by supporting old industries through subsidies and state protectionism. Hence, there is considerable potential for environmental relief if this 'autonomous' industrial restructuring is supported by more market-based industrial policies than the often defensive and structurally conservative approaches that are primarily influenced by the vested interests of affected industries. The primary manufacturing industries still benefit more from industrial policies than sunrise industries, in terms of subsidies and protectionism (Binder *et al.*, 2001).

Due to the manifold issues that need to be addressed, different types of instruments have to be applied, covering regulative and economic environmental policy instruments, all kinds of measures of industrial policies, regional planning, and social policies to compensate possible losers of structural change, and R&D/innovation policies in order to identify other business opportunities. Due to the nature of the policy problems, it is unlikely that persuasive or self-regulatory instruments are of great importance for the management of structural change. The sheer magnitude of the problem also makes it unlikely that distributive instruments can buy out the losers.

Hence, considerable resistance against these policies can be expected, and the few examples for a purposeful industrial restructuring underline this assumption.

With respect to non-governmental actors, trade unions are important actors although they tend to be allied with the business actors in order to prevent major shifts at the expense of their sector and potential loss of workplaces. Environmental NGOs have played an important role in restructuring the chemical industries since the late 1980s (Jacob, 2001), and to abolish nuclear power and integrate environmental objectives in energy policies (Piening, 2001; Foljanty-Jost and Jacob, 2004). The sectors that are subject to green industrial policies are often dominated by multinational companies. Furthermore, the goods produced are subject to international trade and trade agreements. This somewhat hampers national strategies. However, the national level of policy-making remains most important.

To conclude, the proposals, as well as the few empirical cases for a green industrial policy, largely follow traditional modes of governance, in respect of the actors involved, the instruments chosen, and the level of governance.

5. CONCLUSIONS: STRATEGIES FOR INDUSTRIAL TRANSFORMATION

Environmental policies in western industrialised countries initially started by imposing regulations on industries that enforced the introduction of end-of-pipe technologies. For these kinds of policies, the main actors are national governments and the affected industries; new trends in governance are hardly of importance. The picture is different in the case of innovation-oriented environmental policies, where a wide variety of stakeholders becomes involved. Furthermore, much experimentation has been done with new instruments apart from command-and-control regulations. Economic instruments, persuasive and self-regulatory devices (*e.g.* Environmental Management Systems, or liability rules) have been introduced because they leave some room open for industries to develop friendlier environmental technologies. However, such strategies for an ecological modernisation of industries have their limitations: they work only within the logic of markets. For environmental problems that require more fundamental structural changes, which challenge the core technologies of industrial branches, market-based or self-regulatory instruments are of minor importance. Instead, industrial policies are required that integrate many different policy domains and provide a long-term perspective for industrial restructuring. It is unlikely that stakeholder participation or other levels of policy-making than at the national level will be able to trigger such processes.

It goes far beyond the reduction of certain emissions and the clean up of single enterprises, products or branches. It focuses on systems and system changes that are relevant from the view of the global environment — such as the energy system, the food system, and the urban system. The scope for policies that are able to influence and transform such systems is even broader than the policies described in the previous section. A system, in the parlance of industrial transformation, encompasses the value-added chains of several branches, the technologies used, as well as the consumer behaviour, international trade, and the institutional setting at all levels of governance, from local to international.

Some might argue that things are complicated enough already. According to these sceptics, policy-makers hesitate to adopt ambitious polices as they already face the huge demands of an encompassing ecological modernisation, not to mention the requirements of a green industrial policy.

However, broadening the scope brings additional risks as well. For instance, the perspective of value-added chains rather than the polluting branches only, might help to identify the 'weakest' part of this chain. Policies that address the downstream industries might be as effective while meeting with less resistance than addressing the upstream producers. On the other hand, upstream producers often have the capacities necessary to innovate. The broader focus allows assessing which branch might have gatekeeper functions, which are able to innovate, whose interests are affected by change, and who are the most powerful actors. Accordingly, policies can be adapted.

The same holds true for effective interventions by non-governmental actors. Apart from a profound understanding of the institutional conditions and an assessment of the capacities for participation, this is required to identify the appropriate and promising points of intervention.

Based on these considerations, the operating basis for the involvement of non-governmental actors and levels other than the national level of policy-making, as well as introducing new policy instruments, can all be seen from a different angle: if policy-makers currently are not able to impose the required strict regulations, or to set the prices right: what other points for intervention can be found? The systemic approach of industrial transformation research opens up opportunities and requirements to integrate areas of research that were, until now, separated.

To make such integration operational, it is first required to interlink the community of researchers working on national and local industrial transformation policies with those who focus their efforts on international regimes and processes (as elaborated in Section 2).

Second, the focus on systems rather than on specific policies, countries, or institutions, opens up opportunities for interdisciplinary research. The functioning of systems cannot be understood without referring to the economic, technological, or institutional conditions that frame them.

Third, it seems that the adoption of a holistic perspective that focuses on world-wide transformation processes will also require a global and holistic approach for the organisation of research. Understanding the political dimensions of a transition to a non-fossil fuel-based society, for example, requires synthesising a mosaic of local, national, regional and global political processes.

While the traditional study of environmental policy has been devoted to cross-national comparisons, this becomes now even more important for undertaking a 'world environmental policy.' The implications for research practice are particularly salient: the study of a 'world environmental policy' needs not only to analytically encompass all world regions, but must also be internationally organised to make use of the comparative advantages of the local knowledge of particular regions and processes. This calls for diversity within the research community, together with stronger networking applied also to the sub-field of political science. The globalisation of problems can only be countered by the globalisation of political science research. The launch of the IT project within International Human Dimensions Programme on Global Environmental Change (IHDP) has, hence, been a major step forward, and it is to be hoped that more and more national research communities will be better integrated in this global network along the way.

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Chapter 6

ECOLOGICAL ECONOMICS AND INDUSTRIAL TRANSFORMATION

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Abstract: Ecological economics (EE) is an open area of research that addresses economics and ecology in conjunction. It recognises that economies are substrates of our environment, and that the environment sets limits to economic development. Industrial transformation policies, focusing on industrial activities, turn to EE for indicators that relate industrial activity to associated environmental impacts. Methods for ecological bookkeeping of industrial activities constitute the result of practical importance to industrial transformation policy implementation.

Key words: environmental impacts, criticisms of mainstream economics, IPAT account, indicators

1. INTRODUCTION

This paper addresses the question what 'ecological economics' means to 'industrial transformation.'[11] Or, in other words, what has ecological economics to offer to those who study and pursue industrial transformation? What is EE? The academic Journal of Ecological Economics describes itself in the following way: 'the journal is concerned with extending and integrating the study and management of nature's household (ecology) and

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[11] This is more or less the opposite approach of Cleveland's paper "Ecological-Economic Underpinnings of Industrial Transformation (Cleveland, 1999a).

Xander Olshoorn and Anna J. Wieczorek, Understanding Industrial Transformation: Views from Different Disciplines 99–117.

humankind's household (economics). This integration is necessary because conceptual and professional isolation have led to economic and environmental policies, which are mutually destructive rather than reinforcing in the long term. The journal is transdisciplinary in spirit and methodologically open'.

One can clearly see from this quotation that the motivation behind 'EE' is a deep concern about the future, in particular about the danger of human society being adversely affected by dwindling environmental resources. The concerns alluded to above relate to the risk to future human welfare: so phrased, one might say that these concerns have an anthropocentric nature. However, EE also fits the needs of those who are concerned about nature as such. Genuine environmentalists and environmentally concerned utilitarians alike can identify and analyse their worries in the language of EE.

EE has an explicit political flavour, in contrast to 'normal' science, which, disregarding socio-political contexts, just wishes to describe and explain natural phenomena that occur in the world.

Starting from this concern we may identify three main tasks of EE:

- Firstly, EE analyses the relations between the *economy* ('humankind's household') and the *physical environment* ('nature's household,' of which the economy is a substrate) and attempts to identify the relations between economic activities on the one hand and ecological processes and environmental resources on the other hand;
- Secondly, not independently of the analysis of the relation between economy and ecology, EE helps to identify ecologic indicators that are required for policy implementation. Obviously, finding such indicators requires an analysis of and, concurrently, a political agreement about a vision for the ecological future. This indicator work is necessarily interdisciplinary; and,
- Thirdly, EE criticises 'mainstream' economics. EE concludes that only drastic changes in patterns of production and consumption can solve (the persistent) problems, and that 'mainstream' economics — focusing only on marginal economic changes — fails to provide appropriate recommendations for turning economic developments away from ecological disaster.

This paper is structured along these three notions with respect to EE. Section 2 presents a brief sketch of the topics and methods of ecological economics. Section 3 briefly discusses the use of concepts of EE (*e.g.*, indicators) in actual policy making. Section 4 pays attention to the criticism of mainstream economics. Finally, we discuss how EE can contribute to the IT project.

As a final point, from the observation that EE is not an area with strict disciplinary and political boundaries, we note that the present sketch of ecological economics is just one possible account governed by our interpretation of the concept of industrial transformation; other people working in other contexts might well emphasise and evaluate topics of EE differently from the way we do here. They might even not consider themselves as 'ecological economists.'

2. THE ANALYSIS BY ECOLOGICAL ECONOMICS

Modern[12] EE has its origins in the 1960s and 1970s, from concerns about the unsustainable growth of population and economic activity. The bottom-line conclusion of these concerns was that mankind was threatening the natural resources – nature, environment – that constitute the very basis of its existence. In the very first analysis, the threat — environmental impact (**I**) — is the combined result of population growth (**P**), the developments of technology (**T**), and affluence by person (**A**).

I = P●A●T

This account can be developed into a policy model which informs policies that address **P, A** or **T** in order to influence (reduce) **I**. Such a model would be a simulation model if it included time dependencies. One would also have to add feedbacks to capture the effects of Impacts on Affluence and Population. Thinking along these lines has led to compelling concepts such as Boulding's '*Spaceship Earth*' (Boulding, 1966), Daly's concept of a steady state economy (Daly, 1973) and '*The Limits of Growth'* (Meadows *et al.*, 1972). Wilkinson's (1973) study of the 18th and 19th century industrial revolution in the UK provided empirical support to the systems analysis based on the IPAT account. The messages of these studies coincided with those put forward by Georgescu-Roegen (1971). He pointed out that the earth is a thermodynamic system, and that the laws of thermodynamics, in particular the law of entropy, imply that material and energy resources are in finite *useful* supply.

These analyses are at a high level of abstraction, their main function being to direct strategic thinking and to change mindsets rather than to give practical policy advice.[13] To give such advice, each of the four elements of

[12] The earlier economic analysis by the physiocrats — emphasising the resources of nature as production factor — and by Malthus may be considered as the historical analogues of ecological economics.

[13] In fact Meadows *et al.* (1972) predicted that the limits of growth would be reached by now; Georgescu-Roegen's analysis neglected the practical importance of the input of sunlight to the earth system (Kåberger *et al.*, 2001).

the IPAT model would have to be elaborated and connected in more in-depth ways to concrete environmental problems. Table 1 summarises what sorts of issues of policy research the IPAT model entails.

Table 1. Research topics from the IPAT account

IPAT element	Topical research issues
Impacts	Impacts of what (land use, pollution) on what (resources, natural and managed ecosystems)?
Population	What is the scope for population policies?
Affluence	How do economies develop changes in economic structures (sectors) and how to influence them?
Technology	What are the environmental burdens — nature & magnitude — per unit of economic activity per sector, and what would technological change mean to these burdens?

In the study of these four elements, the 'science' of impacts (**I**) and technology (**T**) lags behind the study of demography, and, in particular, economics. Hence, most EE research concerns questions relating to impacts (**I**) and technology (**T**), in the context of 'traditional' economics.

Starting from this IPAT framework, one could say that EE is an effort to integrate 'impacts' and 'technology' into economics and demographics. This raises the questions 'what are impacts?' and 'what is technology?' The next two subsections discuss these questions.

Environmental impacts in ecological economics and in industrial transformation

EE addresses impacts **I** on 'the environment.' What is 'the environment' exactly? What are the units of analysis of something as incredibly complex and all-encompassing as 'the environment,' and what do we actually think of when considering the **I** of the IPAT model? Table 2 gives an overview of two typical accounts of environmental impacts that were supposed to comprehensively cover environmental impacts. The left column shows the categories that were distinguished in an effort to cover all impacts on 'the environment' from a (European) top-down policy making view (Stanners *et al.*, 1995). The right column shows another, rather similar, list of environmental endpoints that also aims to give a comprehensive view of 'the environment.' This list is developed in the context of development of a rather specific branch of environmental policymaking: life cycle analysis (LCA) (Udo de Haes *et al.*, 1996).

Table 2. Two comprehensive systematisations of impacts on the environment

According to the Dobris assessment	According to the LCA account
Climate change	Depletion and competition of abiotic resources
Stratospheric ozone depletion	Depletion and competition of biotic resources
The loss of biodiversity	Depletion and competition of land
Major accidents	Global warming
Acidification	Depletion of stratospheric ozone
Tropospheric ozone and other photochemical oxidants	Human toxicological impacts
The management of freshwater resources	Eco-toxicological impacts
Forest degradation	Photo-oxidant formation (ambient ozone)
Coastal zone threats and management	Acidification
Waste production and management	Eutrophication
Urban stress	Odour
Chemical risk	Radiation
Noise	Noise
	Casualties

From these lists one may distinguish three headline types of impacts:

– Depletion of resources in the sense of extraction of materials (*e.g.* depletion of resources, loss of biodiversity, management of fresh water);
– Emissions and waste production (*e.g.* global warming, eutrophication, noise); and
– Hazards to health (*e.g.* chemical risk, eco-toxicological impacts, casualties).

To what extent are these domains or foci of environmental problems topics of the IT programme? Or, do these problems occur on a global scale, or relate the concerns to problems that can be addressed locally?

In 1972, ‘Limits to Growth’ (Meadows *et al.*, 1972) concluded that, from a global point of view, some (abiotic) resources were at risk of being depleted by the beginning of the 21st century. Today, the problems associated with the use of materials are primarily seen as a waste problem rather than as a problem of depletion (Von Weizsäcker, 1998). Anyway, the current environmental opinion-makers advocate pursuing a drastic reduction of materials use (*e.g.* by a factor of four; Weizacker, 1998). The question is, however, to what extent additional policy is required in order to reach this reduction? Several of the more gloomy expectations of Meadows *et al.* (1972) have not been realised. Apparently, existing institutions and mechanisms (*e.g.* the price mechanism, technological developments) have prevented many problems from occurring on the scale and with the severity that was suggested by the ‘*Limits to Growth*’. Clearly, however, there are important resource problems that are hard to solve. In particular, depletion and pollution of water resources is a major problem. In many parts of the world, agriculture and public health suffer from a lack of fresh uncontaminated water. Erosion of agricultural soils is another serious problem that occurs on a global scale. To address such problems of resource scarcity, systemic changes (*e.g.* institutional reform) may be required. This conclusion also applies to problems of depletion of biotic resources, such as the fisheries, where new management regimes are required in order to avoid the depletion of these resources. Similar approaches are required for the issue of bio-diversity. Bio-diversity captures a range of problems with respect to endangered natural species and eco-systems (*e.g.* tropical rainforests, pristine forests, wetlands). It is directly related to specific economic activities (*e.g.* deforestation and fisheries) and, indirectly, via climate change, to greenhouse gas emissions.

The second domain of environmental problems is ‘emissions and waste production.’ Among the topics from this domain, obviously emissions of greenhouse gases constitute a global problem. Stopping this driver would require a drastic — by at least a factor of four — reduction of the emissions of these gases. Scenario analyses (Houghton *et al.*, 1995) suggest that in the coming decades such drastic emission reductions will be very difficult to achieve. Because of its truly global character and its persistency, the issue of climate change is one of the environmental problems at the heart of the IT project. This is, for instance, unlike the depletion of the stratospheric ozone layer (due to the emission of Chloro-Fluoro-Carbons - CFCs and halons). Agreement on the Montreal Protocol, which bans the use of the substances that deplete the ozone layer, has ‘solved’ this problem (although it will take decades before the ozone layer will be effectively restored). Acidification and eutrophication are both problems that do not have a global nature in the sense of local emissions playing out at global scales. Also, these problems, in particular acidification, have been effectively reduced since the ‘sixties without systemic changes, at least in Europe (EEA, 2002), Japan and the USA.

The third group of problems relates to hazards to life. Major risks are due to the use and emissions of, in particular, Persistent Micro-Pollutants (PMP) or Persistent Organic Pollutants (POP) and their secondary products — *i.e.* chemicals that are formed from chemicals released into the environment, such as endocrine disruptors that are formed from (animal) pharmaceutical products. After WW II, the topic of persistent micro pollutants was among the first to become the subject of a global public discussion (Carson, 1962) and environmental legislation, and, notably, of international environmental agreements. Relative to other environmental problems, the emissions of these substances (*e.g.* cholorofluorocarbons , polychlorinatedbiphenyls, and phthalates) have become less pressing, *i.e.* the discussion about them is less prominent. A major policy in this area is putting bans or strict limits on the production and use of these materials (Opschoor and Pearce, 1991). Producer liability for hazardous effects is likely also a strong incentive for not producing or using certain substances known or suspected to be environmentally harmful.

It appears that ‘persistent pollutants’ do not constitute a persistent problem that can only be solved by systemic changes[14] other than those that have already occurred in the past. This might be one of the reasons for the IT Science Plan not explicitly mentioning the PMP problem. An exception might be, or become, the problem surrounding the use of genetically modified organisms (GMO). This is a problem on which views differ widely across the world.

The IT programme focuses on those environmental impacts that have proven to be persistent — and have not yet been solved — and that play out at a global scale. The above analysis indicates that the activities that industrial transformation research should aim for are, in particular, the ones that cause (*i*) emissions of greenhouse gases, and (*ii*) intrusions on nature leading to loss of biodiversity, and water and land resources.

Technology according to ecological economics

The second subject of analysis of EE according to the IPAT account is **T**:

$$T = I / PA$$

EE (and industrial transformation research) asks, for instance, ‘What is the environmental impact per unit of economic activity?’ and ‘How does **T** develop over time?’

A quick browse through the (macro) EE literature shows that **T** is cast in concepts such as ‘energy intensity,’ ‘materials intensity and materials metabolism’ and ‘resource depletion/dissipation.’ The bottom-line result of many of these studies (See *e.g*. Cleveland *et al.*, 1999a) is that **T** — environmental impact by total affluence — is still too high. This evaluation is, in fact, the rationale of the IT programme. Bringing down **I** by addressing **T** is its ultimate summary. This is, for instance, in contrast to the IHDP research programme’s ‘Institutional Dimensions of Global Environmental Change’ (IDGEC).

[14] This wording implies legislation that regulates the production and use of PMPs (*e.g*. the proposed (October 2003) EU regulatory framework for chemicals REACH (Registration, Evaluation and Authorisation of Chemicals)) is not considered a systemic change.

Maybe it would be worthwhile to note that in the above interpretation, EE **T** does not explicitly refer to technology in the engineering sense; **T** is 'just' a relation between the two variables that are of primary importance: impacts and affluence. This might be the root of misunderstandings between economists and engineers discussing technology: the epistemic roots of the word 'technology' differ for them.

3. INDICATORS

Policy development with respect to complex issues requires these issues to be represented by appropriate indicators. By these indicators we capture and 'sense' a certain issue and can attempt to gain control over it. In the context of the description of the environmental situation and sustainable development, one distinguishes between three different types of indicators: state indicators, pressure indicators and response indicators. State indicators represent the state of the environment (endpoints for the environment); pressure indicators (endpoints of the economy) are used to indicate what processes (*e.g.*, emission, land use) bring about environmental risk, while a response indicator represents societal reaction to the environment being at risk. This system of indicators is called the PSR system (Kuik and Verbruggen, 1991; OECD, 1994).

Below we briefly describe selected environmental indicators for policy-making or indicators that capture the relation between an economic activity and its related environmental consequences. Therefore, we understand them as typical concepts of ecological economics.

Life Cycle Assessment (LCA)

Life cycle assessment aims to assess the environmental consequences of a product or a service normalised by their functional units. LCA produces an environmental ranking of products, other properties of the product or service being equal. Its origin lies in the early seventies in the public discussion about the environmental impacts of beverage packaging. A key characteristic of LCA is that LCA aims to be comprehensive in two senses. LCA should encompass all environmental impacts (See Table 2) associated with a product over its whole life cycle.

One may distinguish between two areas of application: First, LCA helps in the development of products, to compare different alternatives with respect to environmental properties. Second, LCA supports consumers and procurers to compare products with respect to their environmental properties. Environmental labelling (eco-labelling) of products is the major large-scale application of LCA.

LCA is the more effective the less the ranking of the products is sensitive to assumptions in the assessments. Profound problems may arise when the results of the so-called inventory analysis — the tracking of all environmental pressures — must be evaluated, since, for ranking purposes, different types of impacts have to be weighed against each other.

What is the significance of LCA for the IT project? Industrial transformation seeks changes in production and consumption patterns. LCA is a driver of change in different ways:

- LCA supports firms that produce greener products in response to consumers' environmental awareness, and in response to the firms' environmental strategy;
- For producers, LCA is an instrument to analyse a product's sensitivity to environmental developments (*e.g.* policies).

LCA itself does not question the very existence of its subjects (products). Industrial transformation might do that, since industrial transformation is by definition about systemic change. In this sense LCA is less relevant to industrial transformation, notionally. The application of LCA, however, might well initiate systemic change.

Environmental performance of firms

There are numerous schemes for assessing firms' environmental performance (Berkhout *et al.*, 2001; Olsthoorn *et al.*, 2001; Epstein, 1996). The 'environmental performance' indicator actually has wider significance than 'environmental impacts' in LCA, since it may also refer to the environmental management efforts of firms. Measuring the environmental performance (EP) of firms is important in different contexts and is internal purpose useful for environmental reporting and benchmarking.

The 'EP of firms' is relevant to the IT project focus on 'governance and transformation process.' Eventually, some form of environmental reporting by firms is necessary in order to establish whether their economic activities comply with environmental boundary conditions. There is a relation between the way EP will be expressed and reported and the institutional form of establishing compliance (*e.g.*, permit system, emission trading system, voluntary environmental controls).

Firms' environmental reporting is very important for establishing countries' (or whichever political-administrative units') environmental accounts, since reliable accounts are required under any agreed-upon legislative caps for environmental pressures. For instance, under the Kyoto Protocol countries are required to report on their greenhouse gas emissions annually. Compliance with the Protocol will be established on the basis of such reports. Countries have to establish offices to perform the emission inventories. It could well be that, in order to report emissions or full carbon accounts with sufficient reliability, these offices would have to be backed up by legislation requiring all emitters to report their emissions of greenhouse gases accurately. One may compare such a requirement with legal requirements to provide financial information to tax offices.

Substance Flow Analysis (SFA) and Materials Flow Analysis (MFA)

The results of Substance Flow Analysis (SFA) and Materials Flow Analysis (MFA) are accounts of how and to what extent materials are used in an economy (Schmidt and Schorb; 1995). This could be the economy of a country or an area of a country, but it could also be some specific economic activity. SFA and MFA can be compared with the input-output analysis of economies. As such, MFA and SFA are methodologies rather than indicators.

SFA is different from MFA in that SFA refers to a specific chemical substance (*e.g*. PCB, CO_2 or carbon, heavy metals or other substances). SFA is a tool for the development of policies that concern environmental quality (see, *e.g*., Guinee *et al.*, 1999). Substance flow accounts are the unit of analysis for Integrated Chain Management (ICM), and the information source that provides the indicators for performing ICM (Voet *et al.*, 1997).

MFA is often performed in the context of waste policies. Material flow accounting is one of the activities required to set up environmental management schemes, for instance the eco-management and audit scheme (EMAS). Material flow accounts are the actual indicators for monitoring an organisation's environmental performance. As such, MFA is closely related to the rating of firms' (or any other institutions') environmental performance.

Ecological footprint and ecological rucksack

A compelling indicator is the so-called ecological footprint, developed by Wackernagel and Rees (1996). The novelty of this indicator is the metric that is used to express an environmental effect (of a product, a service, an activity or an economy): the amount of space 'used' for enabling an activity. Strong assumptions must be made in order to use this metric. Such assumptions weaken the robustness of any conclusion based on this metric, especially given the lack of appropriate data and the metric's methodological problems.

A particular characteristic of the ecological footprint is that it implicitly assumes that trade is bad for the environment (Van den Bergh and Verbruggen, 1999).

The ecological *ruecksack* is a similarly mono-dimensional indicator for the environmental implications of an activity or product: it uses the amount (kilograms) of waste that is associated with an activity. In light of their limitations, both the rucksack and footprint approaches should be seen as powerful metaphors (Lakoff and Johnson, 1980) that may help to change mindsets, rather than being measures — or units of analysis — for evaluating and monitoring policies that are targeted at specific environmental problems.

Resource efficiency or materials intensity

Several historical studies of resource (or materials) efficiency in relation to the Gross Domestic Product (GDP) have shown that material intensity tends to be low at low GDP; it then increases to reach a peak and then subsequently falls. The conclusion of such observations has become known as the 'green Kuznets curve.' This curve suggests that environmental problems will 'automatically' disappear with economic development. More refined analysis showed this conclusion to be too quick (De Bruyn, 1998; Cleveland, 1999a). This lesson underlines that the more aggregate an indicator is, the less useful it is to guide policy and decision-making (but its communicative power may increase).

Resource Efficiency (RE) is an indicator that is actually established by materials flow accounting. The European Union has adopted this indicator, and a first effort to collect statistical information has been completed (Moll *et al.*, 2003).

Green national income accounts (NIA)

National Income Accounts (NIA) describe and give insights into the performance of economies in monetary terms. An important summary statistic of NIA is GDP. Efforts to correct such accounts (or GDPs) for unvalued (via markets) damage done to environmental resources have resulted in methodologies for 'green accounting.' Green accounting is a framework for simultaneously considering economic and environmental concerns. As such, it has advantages over indicators such as resource efficiencies or the ecological footprint, which do not incorporate the trade-offs inherent in pursuing environmental or economic policies.

The construction of national accounts is complex, and the construction of a green national account is even more complex. Thus far, such accounts are only part of *ex post* analyses of the ‘greenness’ of economies.

Summary of ecological economic indicators

The indicators described above are summarised in Table 3. One may note that the operationalisation of these indicators requires great efforts in finding appropriate data. The sources of information are numerous and different in nature. There is no comprehensive institutional structure that is dedicated to the production of this type of information.

Now and in the future, even after a transformation, there is a strong need for metrics and accurate data to delineate and monitor the environmental conditions to which an economy, and economic activities, should be adhering (for instance, a cap on greenhouse gas emissions). This need can only be fulfilled through a system of comprehensive and accurate environmental statistics. One wonders whether this is possible, considering the current legislation for gathering statistical data by government statistical offices. For instance, there is uncertainty in the numbers in emission inventories submitted to the United Nations Framework Convention on Climate Change (UNFCCC) under the Kyoto protocol, which could eventually lead to difficulties in assessing compliance and in the effectiveness of the flexible mechanisms (*e.g.* Joint Implementation) designed to reduce emissions. Such difficulties might only be solved by legislative changes with respect to the collection of statistical data required by the environmental bureaucracies.

Table 3. Important environmental indicators and domains of application

	Description, characteristic	Stakeholders/Decision makers/domain of application	Comments
Life cycle assessment	Attempts to comprehensively attribute environmental impacts to the life cycle of a product	Product development Consumer decisions. Applied	Applicable if conclusions are not overly sensitive to assumptions in attribution of environmental impacts
Ecological footprint & ecological rucksack	Express all environmental impacts in terms of land use (footprint) or in terms of waste (rucksack)		Compelling metrics, built on heroic assumptions. Not well-suited for ranking policy options
Energy requirements of products-/activities	A form of LCA considering only 'energy use' as the impact indicator	Applied (*e.g.* energy labelling of products)	Relates to a global problem (greenhouse gases) in a targeted way
Environmental performance indicators of firms	Refers to environmental impacts of industrial processes, and to environmental management styles	Benchmarking of industrial processes. Firm's environmental management	This is the beginning of a system for ecological bookkeeping needed to comply with environmental limits
Materials/substance flow accounting	Analysis of the use (flows & stocks) of materials (or substances) in an economy	Policy analysis	Resembles input-output analysis
Green national accounts	A correction of national GDP from environmental damages	National level economic-environmental policies	Integrates environment with economics
Materials intensity/Kuznets curve	Materials intensity per unit GDP. Across economies and over time	Macro-level analysis of the link between economy and ecology	Compelling concept. Evaporates with analysis at more detailed level

Indicators and evaluation

The utility of indicators is that they are metrics for expressing changes in a system. However, the real question is not how to measure physical changes, but how to evaluate them (in order to make a choice). To be able to say whether a change is good or bad — and to determine when policy is needed — one needs metrics, but also criteria for the evaluation of the changes. So, the question[15] becomes how does one, by means of such indicators, rank a range of options that are analysed with respect to their different environmental impacts?

There are at least three answers (Janssen, 1991). The first method is often applied in LCA (the valuation step in LCA). Each alternative (product, for example) is scored with respect to standardised impact categories, and these categories are weighed against each other, possibly by a panel that is representative of the affected public (Udo de Haes, 1996; Volkwein *et al.*, 1996). Weighted scores are tallied into a single score if necessary.

A second method evaluates an alternative for a product (or process, *etc.*) against its potential to reach certain policy alternatives. This is the so-called distance-to-target evaluation. The third answer is from mainstream economics: a policy-maker would base his decision on an evaluation of social economic preferences. This is cost-benefit analysis: the decision-maker asks how does the change in the environment (from an economic activity) affect social welfare? Pollution of the environment can limit or destroy certain functions of the environment that are of use to society. Environmental functions produce such diverse 'goods' as stability of climate, protection against UV rays from the sun, clean air for breathing, water for drinking, various inputs to production processes, and waste absorption. Environmental goods usually have alternative uses: water can, for example, be used for drinking, recreation, biodiversity, for industrial processes, and for absorbing waste (sewage). Once these functions come into, or are expected to come into, conflict (*e.g.* drinking and waste absorption), they become scarce in an economic sense and they acquire an economic value.

However, the economic value of environmental goods is usually not directly observable. Although environmental goods can be regarded as economic goods in many respects, they are usually not privately owned and therefore not traded in markets where goods acquire a price during the interplay of supply and demand. The economic value of environmental goods can often only be inferred indirectly. Several methods are used to assess the impact on the utility of an economic agent of a change in the provision of the environmental good to that agent. The monetary equivalent of that impact on utility determines the willingness to pay for this quantity of the environmental good, or alternatively, the willingness to receive compensation for the loss of this quantity. This willingness to pay (or receive compensation) is the monetary value of the environmental good for that

[15] The question of Multi Criterion Analysis (MCA) (Janssen, 1991)

agent. The negative of this monetary value is the value of the pollution damage that reduces the availability of the environmental good by a specific amount.

A major problem in the monetary valuation of the environment is that the causal links between 'pressures,' 'state,' 'functions,' and, finally, the provision of environmental goods, are often very uncertain or simply unknown. Indicators of environmental quality developed by science and widely used in environmental management are often at the level of pressures or at the level of state, less often at the level of functions, and seldom at the level of environmental goods. Now it appears that these indicators — the endpoints of environmental impact assessment — quantify driving forces and pressures of the environment but stop short of quantifying the provision of environmental 'goods,' *i.e.* those services provided by the environment that are valued by producers and consumers. There is a gap between the endpoints of ecological economic assessment (*e.g.* LCA of a product, or CO_2 intensity of an economic activity) and the economics endpoints (*i.e.* goods and services provided by the environment, human health) that are affected. Economic valuation thus requires an extra analytical step to bridge this gap. It is known that this bridge often cannot be crossed. In this case, evaluation follows from negotiations between stakeholders.

What is the relevance of this analysis of evaluation for industrial transformation? At least one might say that, in general, this framework enhances the transparency of evaluation. By nature, IT projects explore possibilities of systemic changes, so the *ceteris paribus* requirements for economic evaluation are, by definition, not fulfilled. The more a systemic change is involved in an IT policy project, the more economic evaluation will rest on assumptions and the less powerful the economics will be in delimiting the scope of such a project.

4. ECOLOGICAL ECONOMICS AS A CRITICISM OF 'MAINSTREAM' ECONOMICS

The third way in which EE contributes to the debate about the needs and possibilities of industrial transfromation is rather indirect: it is by criticising 'mainstream' economic theory and analysis. The main criticism of EE is that, because of the one-sided focus of 'mainstream' economics on *relative* scarcity and on *marginal* processes, it has lost sight of *absolute* scarcity. Absolute scarcity of environmental and natural resources is governed by the laws of nature, *i.e.* the laws of thermodynamics. An economics that neglect this absolute scarcity and the laws of thermodynamics is not only wrong, but also more importantly, irrelevant (and dangerous in its policy conclusions).

Ecological economics is also critical of conventional welfare analysis that takes preferences of consumers as given, even if these preferences might lead to choices that lead to unsustainable outcomes. One of the goals of EE is then to *highlight* the unsustainability of certain sets of preferences and criticise them, rather than to accept them in a value-neutral fashion. An example is EE's approach to measuring national income. Rather than measuring the actual national income of a country in a certain period, EE is more interested in measuring *sustainable* national income, *i.e.*, the income that *would have been* earned *had* the economy been on a sustainable path. This value-*loaded* approach to economics is a consequence of the political and educational mission of EE.

Much has already been said on these issues and need not be repeated here (*e.g.*, Vollebergh, 1999). EE has failed to convince the economics profession at large that the laws of thermodynamics should indeed be an integral, or even central, part of EE. On the other hand, as Kerry Turner notes in a sympathetic assessment of EE, 'mainstream' economics has progressed towards the ecological view by systematically broadening its scope by 'endogenising' institutions, technology, preferences and the natural environment (Turner, 1999). Mainstream economics has thus widened the constraint set within which economic decisions on resource allocation are analysed. The methodological critique of EE may have contributed to this widening of the scope of analysis. The critique of EE may have altered the mindsets of mainstream economists, and may have made decision makers more aware of the environmental concerns in society.

An important contribution of EE to the study of the economy is its contribution to the 'growth debate.' According to Van den Bergh (2001), the growth debate revolves around three questions: is economic growth desirable? Is it feasible? And is it controllable? EE questions the desirability of economic growth (above the level of basic needs) because it argues that the material gains of 'exploiting' the environment will often not exceed the associated losses to the environment. Because of its negative impacts on the environment, long-term economic growth is also not considered to be feasible. However, EE has not really addressed the question of how a zero growth economy should be managed from a macroeconomic perspective.

Mainstream as well as alternative strands of economics still poorly understand the determinants and consequences of long-term economic growth. This issue is clearly at the heart of the IT project. In its contributions to the growth debate, EE has sometimes mistakenly equated economic growth to material growth. There is no logically compelling reason why the increasing satisfaction of human wants should necessarily be based on an ever-increasing input of material and energy resources. Nonetheless, the 'material' dimension of economic growth, as emphasised by EE, clearly remains an important area of research.

5. CONCLUSIONS

Industrial transformation is not a science or a policy. Rather, these two words stand for the belief that patterns of production and consumption must be drastically altered for future generations to avoid having to live under poor environmental conditions (*e.g.* a harsh climate, lack of biodiversity, lack of affordable energy and water resources) that restrict their ability to achieve a reasonable standard of living.

This insight is essentially a product of thinking in terms of ecological economics (see also Cleveland, 1999a). The analysis of (macro level) trends in the use of energy and materials shows that these trends are by and large persistent. There is some change in the desired direction but this change is marginal in the perspective of global environmental problems, notably climate change, water pollution, land degradation and biodiversity. The persistence of the trends is explained from the combined robustness of technological and institutional structures, *i.e.* the failure of current efforts to reverse trends.

The IT project is justified by these insights. But these insights do not give guidance as to what elements of these technological and institutional structures research should focus on. The insights — from EE — are not sufficiently deep with respect to the mechanisms that explain the persistence of these trends. Such insights are likely to be found in the results of research by scientists working in other disciplinary domains.

EE has put forward several indicators to guide environmental decision-making. What is environmentally benign, however, may not be considered socially benign. In the event of making a choice for a certain policy that has both environmental and social consequences, people are likely to have different appraisals and come to different choices. EE can support discourse and negotiations in order to come to the proper and widely supported policy decisions.

Finally, we raise the question: 'Would there be EE after the transformation?' Our guess is that this would be the case, yet it would probably be limited to keeping the 'ecological books.' In some instances, this situation has already been reached. Some ecological bookkeeping does already occur, notably with respect to emissions of pollutants for which physical limits ('caps') are agreed upon *e.g.*, sulphur dioxide (SO_2), and greenhouse gases under the Kyoto Protocol).

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Chapter 7

AN EVOLUTIONARY ECONOMICS PERSPECTIVE ON INDUSTRIAL TRANSFORMATION

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Abstract: Core concepts of evolutionary economics are applied to the notion of industrial transformation, resulting in an innovative perspective on how to stimulate such a transformation. Evolutionary economics is first discussed at a general level, followed by a review of applications to environmental economic themes. Subsequently, an application of evolutionary economics to the energy system is presented.

Key words: bounded rationality, diversity, energy, environmental economics, innovation, lock-in, path-dependence, selection, transition

1. INTRODUCTION

Industrial transformation research seeks to understand complex society-environment interactions, identify driving forces for change, and explore development trajectories that have a significantly smaller burden on the environment. It is based on the assumption that important changes in production and consumption systems will be required in order to meet the needs and aspirations of a growing world population while using

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environmental resources in a sustainable manner (see Vellinga and Herb, 1999). A more recent term related to industrial transformation is *transition* or *transition management*. Evidently, many traditional insights of economics and policy sciences are relevant to resolving problems raised within the context of industrial transformation. Given that transformations imply a dynamic path from the present, undesirable situation, to a future, more desirable, system, a theory is needed that adequately deals with structural change.

This chapter deals with evolutionary economics, which covers a wide array of approaches with three elements in common, namely, diversity, selection and innovation. The aim of this chapter will be to show that this branch of economics offers a promising approach to arrive at a theory of large-scale socio-economic transitions. The chapter is organised as follows: In Section 2, we will illuminate the main concepts of evolutionary thinking in general terms. Section 3 describes the main contributions to evolutionary economics that can be found in the literature. Subsequently, Section 4 briefly reviews applications of evolutionary economics to environmental-economic issues. In Section 5, the application of evolutionary economic concepts and insights regarding the energy system is discussed. Finally, Section 6 assesses the policy insights that can be derived from an evolutionary economic analysis of transitions.

2. CONCEPTS IN EVOLUTIONARY THINKING

Evolution — either in a biological or an economic sense — involves a number of complementary elements and processes:

- *Diversity (variety, variation):* existence of populations of agents, strategies, products or technologies;
- *Selection:* processes that reduce existing variety;
- *Innovation:* processes that generate new variety (commercial or not), including an initial invention;
- *Inheritance (transmission or retention):* replication through reproduction or copying (imitation); this is the cause of durability (of agents, strategies, products, technologies, *etc.*) and cumulative processes (more complexity, *e.g.*, increased labour division); and
- *Bounded rationality:* individuals and organisations (groups) behave according to adapted or selected habits and routines; they imitate others, and are myopic.

Evolution, being supported by opposite forces or causal processes, is both simple and powerful. On the one hand, it creates diversity through various mechanisms, such as genetic mutations and technical innovations. This can be considered a disequilibrating force. On the other hand, it reduces variety through selection. This can be considered an equilibrating and directive force. Instead of being a law, like gravity, selection is taxonomy of closely related but different processes, *i.e.* it is an umbrella term. For instance, economic selection covers not only market competition but also interactions with labour unions and other interest groups, mergers and takeovers, financial requirements, laws and public regulation, and consumer opinions.

The result of these opposite forces, *i.e.* generation of diversity and selection, is continuous change without equilibrium. The evolutionary dynamics depends on the existing diversity and, in turn, changes it. In other words, without understanding diversity in an evolutionary system there can be no understanding of system dynamics. Note that without innovation and in a constant environment (*i.e.* with constant selection forces), selection will lead to a monotonic path of reduction of diversity that inevitably ends in equilibrium.

The most important possible consequence of sustained evolutionary dynamics is that structure and complexity can arise. This is confirmed and clearly illustrated by numerical evolutionary models and algorithms known as evolutionary computation (Bäck, 1996). Evolutionary theory is, in fact, the only theory that incorporates processes at one level that can create new structures at higher levels. The latter have also been referred to as 'self-organisation' and 'emergence' (Holland, 1998; Kauffman, 1993).

If an evolutionary system has a great deal of diversity, then it is very unlikely that it will revisit a previous state. In effect, this means that history is introduced. And indeed, an important feature of an evolutionary approach is that it can integrate theory and history, in the sense that formal theoretical and historical analyses are complementary and reinforce each other.

The power and attractiveness of an evolutionary approach is that, in spite of a simple conceptual starting point, complex structures can be fully explained on the basis of autonomous, endogenous processes that turn simple systems into more complex ones. As such, one may conclude that evolution is among the most powerful ideas that science has ever generated (Ayres, 1994; Dennett, 1995). But whereas this conclusion is supported by the development of biology over the last fifty years, the realisation of the potential of evolutionary thinking still is incomplete in the social sciences, including economics.

3. ESSENTIAL CONTRIBUTIONS TO EVOLUTIONARY ECONOMICS

This section provides an overview of the core contributions to evolutionary thinking in economics. For more detailed treatments of older work see Hodgson (1993).

Joseph Schumpeter was, without any doubt, the most influential of all early evolutionary economists, both because of his general standing in economics (in Europe as well as the USA) and because of the many important concepts and ideas that sprang from his mind. Schumpeter questioned the static approach of standard economics, and indeed showed a great interest in the dynamics of economies, particularly the capitalist system, in all of his major works (Schumpeter, 1934; 1939; 1942). He considered qualitative economic and technological change in a wider context of social change, focusing on the psychological features and impact of the innovative 'entrepreneur' in his book 'The Theory of Economic Development' (Schumpeter, 1934; first published in German in 1911). Nonetheless, he also believed very much in the value and ideal of equilibrium analysis. One can qualify these different views either as a minor tension or, perhaps better, as two inconsistent perspectives within his economic methodology. Schumpeter regarded economic (capitalistic) change as the result of revolutionary forces from within the economy that destroy old processes and create new ones: 'creative destruction'. This allows for discrete or non-gradual changes (far from equilibrium), which are reinforced by clusters of derived innovations following a major innovation. These themes are elaborated in Schumpeter's studies of business cycles (see subsection on long waves).

Another important notion derived within his dynamic perspective is that of (later called) Schumpeterian versus equilibrium (neoclassical) competition, where Schumpeterian competition denotes a competitive advantage that is realised through innovation or early adoption of a new product or process. Nelson and Winter (1982: 40) note that Schumpeter can be regarded as a 'theorist of bounded rationality'.[16]

Schumpeter's writings do not build upon explicit evolutionary notions and terminology, even though his work perfectly connects with modern evolutionary economics. This has been explained by the fact that the formulation of most of his important ideas took place before the evolutionary

[16] The term 'bounded rationality' is used to indicate that (contrary to neoclassical assumptions) individuals and organisations (groups) do not always behave completely rationally: they behave according to adapted or selected habits and routines; they imitate others, and are myopic.

synthesis of genetics and Darwinian theory, which ultimately led to broad acceptance of evolutionary theory within the realm of biology.

Maximisation by market selection: Alchian and Friedman

Alchian (1950), Friedman (1953) and Winter (1964) are the core references in the debate on the behaviour of firms in economics. Alchian argued that it is unnecessary to assume profit maximising or even profit seeking as a fundamental and universal characteristic of firms, because firms that are profit seekers and successful in realising profits will be selected (Alchian uses the term 'adopted') by the market mechanism and survive. Friedman (1953) went further than Alchian and argued that profit 'maximisation' rather than 'seeking' is selected by the market, thus trying to find support for the idea that profit maximisation will be the sure outcome of selection by the market. How exactly are the 'assumption' of profit maximisation and the 'fact' of maximisation different? Why is this significant?

Winter (1964) criticised both previous authors for using the selection analogy from biology without complementing it with a clear inheritance mechanism or sustaining feature assuring constant or replicated behaviour over time. Even without randomness of firm behaviour or the economic environment, *i.e.* with 'habitual behaviour', it is impossible to select firms that consistently realise (let alone maximise) profits over time. The reason is that selection is based on the outcome ('phenotype,' in evolutionary biology terms), which has no relationship with the inheritance unit ('genotype'). In less technical jargon, one can say that winning in one period is unrelated to winning in another period. If profit seeking or maximising is not deliberate or conscious, then it cannot be passed on to, or learned by, others; *i.e.* winning remains a largely random process, witnessed by the fact that profits of firms fluctuate erratically over time.

Finally, various factors can weaken the selection mechanism itself. For instance, in the case of lax competition, selective pressure will be weak. The market forces may be counteracted by additional selective forces, such as political or policy constraints, including environmental regulation (Foss, 1993).

Routines and search: Nelson and Winter

The most cited and perhaps most influential work since the 1950s has been that of Richard Nelson and Sydney Winter, which culminated in their famous 1982 book 'An evolutionary theory of economic change'. Not only has it influenced evolutionary economists in the neo-Schumpeterian tradition, but it has also been taken most seriously of all evolutionary writings by mainstream economics. The reason the book was so influential is that it proposes a formal, axiomatic approach to evolutionary economics. It offers a very precise approach that allows for operationalisation in theoretical models and empirical, statistical applications, such as a replication of economic growth during part of the 20th century.

Nelson and Winter propose that '…a major reconstruction of the theoretical foundations of our discipline is a precondition for significant growth in our understanding of economic change'. They focus on firms and gradual change, assuming that firms are '…motivated by profit and engaged in a search for ways to improve their profits, but their actions will not be assumed to be profit maximizing over well-defined and exogenously given choice sets' (Nelson and Winter, 1982: 4). Moreover, regarding their analysis, they state: …'we do not focus our analysis on hypothetical states of "industry equilibrium", in which all the unprofitable firms no longer are in the industry and the profitable ones are at their desired size'. Nelson and Winter argue that their evolutionary theory can do basically what neoclassical theory can do, and much more, such as dealing with micro-level policy, and providing information on (changes in) the distribution of firm characteristics.

One can say that Nelson and Winter interpret economic evolution as gradual micro-level changes of routine-like behaviour through search processes. The three building blocks of their theory of microevolution are as follows:

- *Organisational routines:* This covers the way in which business is done and decisions are made. That firms have routines makes sense given that they face transaction costs, behave according to bounded rationality, and do not change their behaviour in the short run. A routine can be considered as the equivalent of the gene in biological evolution (though it is obvious that the two concepts are not entirely similar). Routines have been equated to habits, but it seems better to make a clear distinction between habits, skills and routines. A skill is defined as: '…a capability for a smooth sequence of coordinated behaviour that is ordinarily effective relative to its objectives' (Nelson and Winter, 1982: 73). Skills are tacit knowledge that does not involve deliberation and conscious choices, but operates automatically. Like a skill, a routine can be considered as programmatic. The difference is that, unlike a skill, it does not apply to individuals but to organisations like firms. A routine consists of an adapted, complex set of skilled individuals who interact simultaneously and sequentially;
- *Search behaviour*: Routines create a constancy or continuity in the firm's behaviour. This is due to a number of factors. Starting from the notion of

a routine as a complex set of interactions among skilled individuals, Nelson and Winter also mention politics, avoiding conflicts, vested interests, and financial costs of change as the main factors. An additional factor is evidently management control systems. Nevertheless, routines can and do indeed change. Change can follow a number of routes. An evaluation of current routines leads to smaller or larger changes in, or even replacement of, routines. Organised search based on separate organisational units, itself following routines, is a major activity aimed at changing existing routines, covering potentially everything from products and processes to marketing strategies and internal organisation, *etc*.; and

– *Selection environment:* This influences the performance of the firm as well as changes in the firm. Selection results mainly from demand and supply in markets, institutional and policy constraints, and the (strategic) behaviour of other firms. Nelson and Winter do not say that much about the types of selection, and downplay it as compared to the role of routines and routine change. They distinguish selection from imitation, and argue that the first dominates in biological systems, whereas both are important to economic systems (Nelson and Winter, 1982:142-143).

Long waves

When analysing evolutionary economics' contributions to transformation research, it is also necessary to consider the phenomenon of long waves, which, besides growth, falls under the heading of the long-term impacts of technological innovation. Long waves can be defined as cycles of prices, wages, and outputs of specific commodities (*e.g.* coal, iron), foreign trade, interest rates, and various other economic variables. The notion of waves or cycles suggests up and downswing, or rise and decline, or boom and depression. Many different opinions have been expressed regarding the nature of waves as well as their causes (see the marvellous collection of classic articles in Freeman, 1996). Long waves are often regarded as being caused by major shifts in technology, due to fundamental advances in science. Freeman points out that various writers do not believe in the existence of long waves, even if they — evidently — recognise fluctuations in economic variables over time. The problem arises from the combination of the complexity of long-term history, and the difficulty of empirically assessing the precise causality behind the composition of long-waves phenomena. Reconstruction of historical data and statistical problems related to 'de-trending' cause additional problems.

Nevertheless, various types of cycles or waves have been identified (*cf.* Freeman, 1996):

- Kitchin cycle: forty months: related to keeping inventories; nowadays, similar short cycles may be due to political (election) cycles;
- Juglar or business cycle: 7-11 years: related to adjustment of investment in fixed assets responding with delays to price changes, *i.e.* inequality of demand and supply;
- Kuznets cycle: 15-30 years: this has been noted especially in the US and has been explained by waves of migration (possibly self-generating or endogenous through pull forces exerted by an upswing in the wave) and weather (exogenous ‘luni-solar tides’ affecting rainfall and, in turn, crop production); and
- Kondratieff cycle: 40-60 years: Different particular explanations of long Kondratieff waves have been suggested. From an evolutionary angle, the most important explanation is that the source of new paradigms (*e.g.* fossil fuel-based industry, electricity) are radical innovations supported by fundamental advances in science, which run through particular sectors and firms that have a direct link between fundamental innovations and their processes and products, and which are most direct and influential in early stages of new technological paradigms. These advances are supportive of many processes and products, directly, or indirectly through process and product innovations. As a result, the innovative key factor or technology generates many related innovations (processes and products), causing a clustering in time of innovations. Together with a phenomenon similar to the product-life-cycle over time, characterised by an end phase of saturation, senescence and diminishing returns, to further investments and marginal improvements in the dominant technology, this clustering of innovations gives rise to patterns that can be interpreted as long waves.

Path-dependence and lock-in

Strategic competition (prices, features) occurs among technologies in markets. The more a technology is adopted, the more attractive it often becomes. This is known as self-reinforcement, positive feedback, and increasing returns. The concepts that are used in explanations of this phenomenon are diverse (partly based on Arthur, 1989):

- *Scale economies:* cost and price decrease as the scale of production increases;
- *Learning by using or doing:* improvement, lower costs (producer), better performance (consumer);
- *Imitation or bandwagon effect:* consumers tend to copy each others’ purchasing behaviour;

- *Agglomeration effects:* spatial spillovers that give rise to positive externalities;
- *Network externalities:* being connected to a larger network (*e.g.* via phone) often has an advantage. A self-fulfilling prophecy is often at work here: what potential adopters believe or expect to be a large network in the future will as a result become a large network;
- *Dynamic efficiency:* the more a product or technology is adopted, the more resources will be available for its development and perfection, which, in turn, will make it relatively attractive for potential adopters;
- *Informational increasing returns:* if a product is adopted more, and therefore becomes better known, then risk-averse individuals will more easily be convinced to buy it;
- *Technological inter-relatedness:* infrastructure and sub-technologies are often complementary (gasoline, refineries, filling stations, car technology). Sometimes this is referred to as co-evolution; and
- *New knowledge is shared by firms:* firms increase knowledge due to learning-by-doing and innovation, which can be shared with other firms in the same sector with similar problems. This leads to dynamic increasing returns at the level of industries.

Increasing returns is important in competition among alternative technologies. The technology that, by coincidence, gets a larger market share, has an advantage and can grow relatively quicker (attain a larger market share) or grow at the cost of others. In other words, there is no perfect competition. In technical terms, multiple equilibria exist: the paths towards these equilibria are important, and are typically the study area of evolutionary economics.

An important consequence of increasing returns is that the (adoption) process towards the final or equilibrium state of the system is path-dependent (non-ergodic), *i.e.* it depends on the way adoptions are built up. Path-dependence can be interpreted as temporally remote events having a significant or dominant impact on the present. The logic of the world can be understood only by uncovering how it got this way (David, 1985). Note that path-dependence is in a fundamental way related to evolutionary systems. The reason is that when large diversity changes over time due to selection and innovation, based on probabilistic reasoning alone (large numbers) it is extremely unlikely that an exact earlier state with all its diversity is revisited.

Diversity at every point in time is, then, unique. Path-dependence thus implies irreversibility. Note, however, that path-dependence is not the consequence of purely random factors, but results from interaction between random and systematic or deterministic factors. Path-dependence can result in lock-in, possibly of inefficient (sub-optimal) equilibria. Lock-in means that a dynamic pattern of competing technologies ends up in a situation with one technology dominating the market. Moreover, the system is inflexible and irreversible, *i.e.* one cannot easily escape this situation. Unless this technology becomes obsolete, or a large scale, coordinated effort is undertaken to change the technology, lock-in will be extremely durable — with all the social costs involved in the case of an inefficient technology. In Section 6 more will be said about the policy implications.

There is ample empirical support for lock-in and path-dependence due to increasing returns:

– The QWERTY typewriter/keyboard, where the alternative is Dvorak;
– VHS video systems, its alternative was Betamax;
– Alternating current (electricity), the alternative being direct current;
– Internal combustion engine in car technology, the alternatives are the electric, fuel cell and hybrid engines, as was the steam engine;
– Microsoft DOS and later Windows operating systems for personal computers, the alternative is Linux.

Connections and discrete mathematics: Potts

An important recent proposal for a direction evolutionary economics could follow, is formulated by Potts (2000). He presents a kind of axiomatic foundation of evolutionary economics. In his view, economic systems are complex 'hyperstructures', *i.e.* nested sets of connections among components. Connections can reflect physical connections such as among components in products or machines, but also material and information flows among individuals or departments within an organisation. Against this background, economic change and growth of knowledge are in essence a process of changes in connections. This is evident: new products, new firms and new sectors arise and old ones disappear, while firm 'growth' and economic 'growth' are essentially processes creating new and losing old connections, as well as grouping those connections or hyperstructure dynamics.

In line with the idea of changing connections, Potts calls for a new microeconomics based on the technique of discrete, combinatorial mathematics, like graph theory, to study the change of microeconomic connections. In addition, Potts' approach can be seen as a fundamental discussion of the need for multi-agent or population models[17] (not to be confused with multi-sector models). He also seems to suggest that all connections have a spatial dimension as well, implying the relevance of the 'geometry of space'. The idea of nested connections is consistent with other

[17] Also known as 'artificial life' or 'artificial world' simulation models.

work in evolutionary economics, notably Nelson and Winter's notion of firm routines as consisting of interactions among skilled individuals.

Potts opposes this view of nested connections to that of traditional microeconomic equilibrium theory. This theory in essence assumes a continuous reality, which is convenient as it allows the application of concepts like equilibrium, representative agent, production function, and utility frontier, as well as applying techniques like integral and differential calculus. Potts argues that microeconomic equilibrium theory cannot address such notions as complexity and its change, heterogeneity, modularity and decomposability.

Current schools of economic evolutionary thought

Neo-Schumpeterian theories of technical change currently dominate the evolutionary approach in economics (Dosi *et al.*, 1988; Metcalfe, 1998; Witt, 1993). These authors study phenomena at the firm level (technological innovation), the market and sector level (competition and diffusion, change in the sectoral structure), and at the macro-level (growth, long waves and international trade). They recognise that the impacts of firm-level innovations are manifold: Innovation causes asymmetry in technology among firms, sectors and countries, leading to exchange and trade. Comparative advantages are not fixed but change due to innovation and diffusion. Trade itself stimulates diffusion of knowledge. In addition, technological change affects the division of labour, the organisation of intra-firm and inter-firm relationships, and thus the industrial structure and patterns of intermediate deliveries. Moreover, some firms try to broaden their range of activities and products (maintain variety), not just to realise economies of scope (savings on unit-costs and lower product prices due to joint overhead, or joint production in the case of multiple products generated by a single firm), but to be resilient in the face of market and competitive selection. User-producer interactions may be important as well, such as geographical and cultural proximity, which can give rise to national or regional systems of innovation.

A second current school that is becoming more influential is evolutionary game theory (Friedman, 1998a; 1998b). It has three roots, although this is not often acknowledged. The first is formed by the writings of Alchian and Friedman, who attempted to found equilibrium theory on evolutionary theory. Indeed, evolutionary game theory is also known as equilibrium selection theory, because it solves the problem of multiple equilibria common in non-linear economic equilibrium models. The second root is the group of Chicago economists of the 1970s who studied selection, took ideas from socio-biology, and developed theory around the notion of utilitarian or selfish altruism — altruism that contributes to one's own utility (Becker, 1976; Hirshleifer, 1977; Tullock, 1979). The third root is the method of evolutionary game analysis based on populations and selection, which was developed in biology (Maynard Smith, 1964; Maynard Smith and Price, 1973; Maynard Smith, 1982). This method was originally used to support insights from socio-biology.

Evolutionary game theory focuses on the existence of asymptotic equilibria, *i.e.* equilibria that result from repeated selection. These are possible because no attention is given to a structural process of diversity generation, as a result of which selection completely dominates system dynamics. In other words, the interaction between innovation and selection, typical of evolution in reality, is missing. A more suitable name for evolutionary game theory is thus 'selection game theory'.

In the following sections we will examine possible links between evolutionary economics and environmental themes, notably industrial transformation and the transition to a sustainable energy system.

4. ENVIRONMENTAL APPLICATIONS OF EVOLUTIONARY ECONOMICS

Nicholas Georgescu-Roegen (1971) emphasised the irreversibility of long-term economic development as a consequence of the laws of thermodynamics, notably the entropy law. In addition, he has suggested the 'exosomatic development' of humans as a step in our evolution to overcome our biological, endosomatic shortcomings as humans. In this context, he has identified three technical, exosomatic 'Promethean' innovations as crucial for important changes of economic production over history: fire, agriculture and the steam engine (Mesner and Gowdy, 1999). Nevertheless, even though the continuation of Georgescu-Roegen's work is sometimes referred to as 'bioeconomics', his work cannot be considered as truly evolutionary; it does not refer much to specific evolutionary mechanisms, and at best uses a very loose interpretation of economic evolution.

Coming from a similar background, namely combining economics with environmental concerns, Kenneth Boulding (1978; 1981) aimed to change economic methodology by using ecological and biological evolutionary analogies, notably ecological equilibria, ecological stability and homeostasis, and population (see also Penrose, 1952). He also proposes an analogy with regard to the distinction between genotype and phenotype (operationalised later by Faber and Proops, 1990).

Two other authors motivated by environmental concerns are Norgaard (1994), who introduced a wider interpretation of co-evolution, namely as a joint and interactive evolution of nature, economy, technology, norms, policies and other institutional arrangements, and Gowdy (1994) who combines the notion of co-evolution with macro-evolutionary elements. Indeed, economic evolution is now often regarded as a process at multiple scales, which is consistent with hierarchical approaches to economic evolution (see van den Bergh and Gowdy, 2003; and Potts, 2000).

Wilkinson (1973) has developed an ecological theory of economic development that aims to link the Industrial Revolution to natural resource factors (see also Common, 1988). His theory recognises a number of human strategies to respond to resource scarcity, such as new techniques, new resources, new goods, birth control and migration. Wilkinson's ideas imply an environmental perspective on the origins of the Industrial Revolution at the end of the 18th century. The Industrial Revolution started with agriculture (using large amounts of land) and iron smelting (using large amounts of timber for energy purposes), in turn giving rise to a significant loss of forest cover in England. The resulting shortage and related high price of wood stimulated the use of coal. In an early phase, this focused on coal mining in strips at the surface. Later, deep mines were explored. This created an important problem, namely that groundwater needed to be pumped out. This allowed the first large-scale application of the steam engine. In turn, widespread use of the steam engine gave rise to various refinements of the steam engine and competing alternative models. In a subsequent phase, spin-offs to other sectors occurred, especially the textile industry and transport through ships and trains powered by steam locomotives.

Faber and Proops (1990) propose a neo-Austrian approach for evolutionary elements, to simulate economic and environmental history from a pre-industrial agricultural society to an industrial society using fossil fuels and capital. They emphasise the role of time. Their approach allows for the irreversibility of changes in the sector structure of the economy, for uncertainty and novelty, and for a teleological sequence of production activities (roundaboutness). In this approach, the long-term relation between environment, technology and development is then characterised by three elements:

– The use of non-renewable natural resources is irreversible over time, so a technology based on them must ultimately cease to be viable;
– Inventions and subsequent innovations lead to both more efficient use of presently-used resources and substitution to resources previously not used;
– Innovation requires that a certain stock of capital goods with certain characteristics be built up.

They construct a multi-sector model of which the production side is formulated in terms of activity analysis. This model allows studying the effect of invention and innovation on a transition from a situation with simple to more complex or roundabout production activities. Roundabout activities use multiple technologies. For instance, food production has become more roundabout, moving from agriculture with labour, through agriculture with labour and capital, to a large food processing industry with many intermediate deliveries. This approach is extended with the technology effects of resource scarcity as indicated above.

A few other studies have employed evolutionary models of growth with environment and resources that generate similar patterns (Clark *et al.*, 1995; Galor and Moav, 2002). For related models see Noailly *et al.* (2003) and Noailly (2003). Epstein and Axtell (1996) present a unique model that combines economics, resource, culture and many more aspects in a single, spatial multi-agent model with evolutionary dynamics. These models are all theoretical.

5. AN APPLICATION TO THE ENERGY SYSTEM

Energy supply and demand is an area where evolutionary economic analysis could yield particularly fruitful results. Decisions concerning the purchase and use of energy-consuming appliances are largely determined by fixed habits and patterns, rather than by optimising processes involving all available information on alternatives and their consequences. Several studies have shown that energy conservation options that are profitable according to theory are not applied in practice (*cf.*, *e.g.* Velthuijsen, 1995; Brown, 2001). This example shows that energy use by consumers and firms is often characterised by bounded rationality.

Irreversibility and path dependence are important characteristics of the energy supply system. Historical investments in energy infrastructure may lock-in the system for a long period, making it unattractive to switch to a different fuel or to a new technology for energy conversion, for instance.[18] Another example of irreversibility can be found in the area of energy conservation. Haas and Schipper (1998) have shown that the price elasticity of the demand for electricity by households during price increases and during price decreases is not the same. The difference can be explained by the fact that investments in energy-saving measures that are made during

[18] Nevertheless, a limited amount of scope for substitution will often exist. For example, gas fired power plants can often switch to oil if needed; coal fired plants can be co-fired with biomass, and natural gas pipelines could (with some adaptations) be used for transport of other gases (such as hydrogen) as well.

periods of rising energy prices will not be undone when energy prices start falling again.

Path dependence and the associated lock-in imply that at an early stage several energy technologies may compete, but in the course of time one of them will tend to dominate. This may have several causes: network effects on the supply side; learning effects for the technology that happens to grow just a little bit faster at the beginning; available complementary technology (*e.g*. petrol supply is based on refineries, petrol stations and a powerful car industry); economies of scale and sharing of knowledge; and the attractiveness of standardisation for the consumer.

For a number of reasons, the possibility of lock-in effects (with resulting sub-optimal outcomes) is rather high in energy supply. First, the technology involved is usually large-scale, network-based, and has relatively high 'sunk costs'. Investments made in the past (often supported by government subsidies) may severely limit the opportunities to apply new technologies. For example, EDF (the French state power company) has promoted the electrification of the French countryside (using cross-subsidies from urban consumers) and stimulated the use of electricity for heating, thus putting local, renewable energy sources at a disadvantage (*cf*. Bonduelle *et al.*, 1998). Secondly, the functioning of an energy network requires uniform standards, *e.g*., concerning tension and frequency levels in an electricity grid, or the quality of natural gas. This limits the options to transport energy from non-conventional sources through the grid. Thirdly, energy technology is usually knowledge-intensive and learning effects are considerable. Energy companies often prefer to continue (and optimise) those activities at which they are already quite good, rather than enter into experiments with technologies that are new (for them). This is illustrated by the fact that the cogeneration (combined heat and power) boom in the Netherlands was not initiated by power producers or distribution companies, but by the energy-intensive industry (*cf*. Blok, 1993).

In the energy area, many examples can also be found of co-evolution. For instance, the development of gas turbines for electricity production and the development of jet engines for airplanes are closely linked. Technology from aircraft industry is also used in designing rotor wings for wind turbines. Furthermore, the development of solar panels for the aerospace industry provides a considerable 'spin-off' for applying photovoltaics in electricity supply on earth. These examples relate to co-evolution of similar technologies in different applications and sectors. In addition, we can observe co-evolution between energy technology and its (institutional) environment. For example, the development of small-scale cogeneration and other decentralised power generation systems led to the need for regulations and agreements concerning the conditions and prices for feeding this power into the grid. In turn, these rules facilitated the further development and application of decentralised power production.

Despite the existence of lock-in effects, heterogeneity and diversity of techniques and organisations can also be encountered in the energy supply system. Within Europe, one can observe substantial differences between countries regarding the dominant source of primary energy for their power production: nuclear (Lithuania, France, Belgium), coal (Poland, Germany, Czech Republic, Greece, Estonia), natural gas (The Netherlands) and hydropower (Iceland, Norway). In Denmark and The Netherlands, the share of cogeneration in electricity production is much higher than in other EU countries (European Commission, 2002). Even within one energy source, technological heterogeneity between countries can be distinguished: in applying nuclear energy, France has specialised in pressurised water reactors, the USA in boiling water reactors, the British in gas cooled reactors, and the Canadians in reactors cooled by heavy water (Van der Zwaan, 1999). These differences are not only related to differences in national availability of natural resources and other comparative advantages, but also to the national energy policies that have been pursued in the past. Obviously, government interference can have a strong influence on transformations in the energy industry.

Disequilibrium is a prominent feature of many energy markets as well. This is illustrated by the large price fluctuations especially in the oil and electricity markets. However, these disequilibria do not primarily stem from market power obtained through technological superiority (as evolutionary economics assumes), but rather from political-strategic factors (OPEC, Iraq *etc*.), unpredictability (economic activity, cold winters), and (in the case of electricity) the technical need to maintain a constant balance between supply and demand (no stock formation possible). In any case, market power is an important issue in energy markets, even though it is at present probably not based on technological superiority. Until recently, the situation was actually often the other way round: the (regulated) monopoly position of energy companies enabled them to invest in risky technologies, which they probably would not have done in a competitive market.[19] To what extent power companies will pursue market share in the present liberalising market by means of a technological lead remains to be seen.

To wind up, we can conclude that many of the core concepts of evolutionary economics readily apply to the system of energy supply and demand. With a view to achieving a transition or transformation towards a

[19] For instance, in the beginning of the 1990s the Dutch public power conglomerate Sep invested some € 350 mln in an experimental coal gasification plant, without having to worry about financial problems in case of disappointing results.

sustainable energy system, evolutionary economic analysis might contribute to better insights into, and understanding of, the energy system, and ultimately to better recommendations for policy makers. In the next section we will take a closer look at the kind of policy recommendations that can be expected to ensue from such an analysis.

6. EVOLUTIONARY POLICIES FOR INDUSTRIAL TRANSFORMATION

A qualitative evolutionary analysis of industrial transformation leads to a number of policy insights. A very general policy suggestion is that to maintain an adaptive and resilient system, variety should be fostered at various levels: firms, technology, knowledge, R&D efforts, and schools or paradigms in science. Fisher's theorem is worth mentioning here: 'The greater the genetic variability upon which selection for fitness may act, the greater the expected improvement in fitness' (Strickberger, 1996: 510). This theorem implies that the propensity for variability will itself improve through repeated selection, *i.e.* variability itself is selected. Focusing on a single best available technology (BAT) is risky from this perspective as knowledge about potential changes and impacts is always incomplete and lock-in of the BAT can occur.

Alternative policy suggestions can be derived from evolutionary economic thinking by considering the basis of bounded rationality. Consumers and firms often show habitual behaviour, and tend to imitate others, especially in complex and uncertain situations where information gathering is costly. Van den Bergh *et al.* (2000) come up with a number of policy suggestions. Habitual behaviour is one explanation for the 'energy gap', *i.e.* the unreaped economic benefits associated with potential energy conservation measures inside many firms. Behaviour according to lexicographic or hierarchical preferences — needs have a hierarchical structure with lower and higher needs, and higher needs do not appear before the lower needs are covered (consumption up to satiation) — implies that the substitution of commodities in terms of utility is limited or even impossible (Stern, 1997). This underlines the empirical fact that growth of material consumption beyond lower (material) needs (basic food, clothing, shelter) has occurred at the cost of 'immaterial' needs, such as rest, absence of stress, personal contacts, social life, serenity (no noise), no violence, *etc.* Lexicographic preferences also suggest that individuals are unable to make a continuous trade-off between environmental functions or resources and economic goods. Policies aimed at material growth beyond basic material needs should be considered more critically against this background.

Uncertainty is an important facet shared by evolutionary thinking and industrial transformation. Several theories can be applied to address it. Prospect theory and regret theory stress the asymmetry with which individuals perceive and deal with gains and losses (Kahneman and Tversky, 1979). This may affect how individuals negotiate: negotiations between polluters and victims; negotiations between countries about environmental agreements; or negotiations between regulators and polluters about the initial distribution of permits. Roe (1996) applies 'Girardian economics', which is a theory of individual behaviour in the face of pervasive uncertainty. It suggests that such uncertainty elicits mimetic behaviour (imitation), which in turn leads to reduced economic diversity of behaviour, strategies, activities, ideas, products, *etc*. Setting a clear overall goal like the 'zero emission vehicles' in California is an example of how the requirement of reducing policy uncertainty can be met.

The idea that preferences are changing and endogenous instead of invariant has led Norton *et al.* (1998) to argue that changing consumers' preferences can be an instrument of environmental policy. In particular, they state that stable preferences are at best realistic over short periods of time, and that sovereign preferences are inconsistent with long-term goals of sustainability. Consequently, in this line of reasoning, public discussion about the ethics of consumption and sustainability should be stimulated via education, advertising rules, cultural norms, *etc.* Changing consumers' preferences through democratic processes could be used to encourage environmentally conscious consumption in a way that consumers would not feel 'deprived and unhappy' but 'enlightened and happy after being educated' (Norton *et al.*, 1998: 203). Most democratically elected governments formulate public policies already aiming at influencing norms, which are regarded as criminal, racist or otherwise undemocratic. A policy aimed at changing preferences is consistent with the evolutionary economic notions of imitative behaviour, diffusion of lifestyles, and creating an adequate selection environment, in this case through information provision and education.

Beyond a certain technical or geographical scale of innovation, governments might have to take control of fundamental R&D through universities and technological institutions. This situation arises because the link between R&D and profit making becomes too indirect or uncertain. Basic (university) research provides the basis of major technological changes, such as pathway technologies, and can help in avoiding a path of diminishing returns. In addition, social or organisational innovations may need governmental support, such as car share or mixed car-public transport systems. Pathway technologies, which have a large impact on many developments and activities through connections to all kinds of uses and other technologies, deserve much attention. For instance, energy storage is important, as it supports renewable energy use, solutions to electricity peak demand, and zero emissions car technology.

The most important questions in the context of industrial transformation are: how do regime shifts occur?[20] And, how can they be stimulated? Two ancillary questions are: how can lock-in of inefficient or undesired technologies be avoided?, or, once it has occurred, how can it be undone? Preventing early lock-in in the future, which is probably less cumbersome and costly than breaking out of an historical lock-in situation, requires portfolio investment. Un-locking of undesired structures and technologies, from an environmental or some social welfare perspectives, may not be realised by merely 'correcting prices', but may require a combination of policies.

One way to foster technological variety and diversity is to create and maintain 'niches' for specific technologies: market segments, relatively sheltered from the rest of the market, where the new technology can be further developed, up to the stage where it can benefit from scale and learning effects. In the past, such niches could often be found in sectors of the economy where public ownership and regulations dominated, such as energy, transport, and telecommunications. Market liberalisation and privatisation have reduced the potential for such niches, implying a need for new arrangements to create niches. Creating semi-protected niches may be successful in stimulating renewable energy sources, notably solar energy based on photovoltaic cells (Kemp, 1997). Other elements of a strategy to avoid lock-in or unlock include stimulating a diversity of R&D, stimulate pathway technologies (electric batteries) and complementary technologies. Of course, price-based instruments are still important, focusing on cost-effectiveness and 'dynamic efficiency', but they may not be sufficient.

To wind up, the main implications of evolutionary economic insights for industrial transformation policies relate to:

- Fostering variety and preventing lock-in (*e.g.* by maintaining a broad range of basic and applied R&D activity);
- Stimulating deviations from habitual and routine behaviour; and
- Creating a favourable selection environment for new technologies, among others, by means of education and regulation, and by creating niche markets.

Further research is needed to arrive at more specific and operational policy conclusions. Such research could focus, for example, on the relationship between the learning curves of new technologies and the size of the niche markets needed to make them competitive. It could also address

[20] See Chapter by Geels in this book.

the dilemma between maintaining diversity and reaping the benefits of economies of scale in a systematic way. Finally, the importance of co-evolution and exchanging and combining information (routines, knowledge) between different industries so as to arrive at major innovations could be investigated empirically.

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Chapter 8

A NEO-CLASSICAL ECONOMICS VIEW ON TECHNOLOGICAL TRANSITIONS

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Abstract: Neo-classical economics assumes rational behaviour of economic subjects. The aim of policy makers is to maximise a broadly defined concept of social welfare, which may include some measure of environmental quality. In this view government intervention is needed when, due to externalities or other reasons for market failure, individual optimising behaviour does not lead to a socially optimal outcome. Therefore, neo-classical economics provides useful insights about the reasons behind technology lock-ins, and whether technological transitions are needed to escape from such lock-ins in order to enhance social welfare in the long run. This paper gives, from the neo-classical perspective, a survey of the state of the art of economic thinking on lock-ins, technological change and the possible role of the government to correct market failures by promoting technological transitions.

Key words: neo-classical economics, economic growth, lock-in, technological change, externalities

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1. INTRODUCTION

To some extent, environmental policy has been effective in the last decades. Environmental problems have been solved and pollution has decreased in a number of cases where the problems had a local scale and where the consequences of the pollution could be observed directly by the stakeholders. The OECD (2001) has labelled as 'green' problems that relate to traditional forms of industrial pollution, such as air and water pollution. Yet a new generation of problems that remain unsolved may have a much more fundamental impact on society than relatively simple 'green' problems. These are the 'wicked' environmental problems that are labelled 'red' by the OECD. A characteristic of these problems is that their consequences are not directly observable; due to large international externalities, they require policy co-ordination on a worldwide scale (see also WRR, 2003). The major example is the emission of greenhouse gases and the resulting global warming. Other examples are the loss of biodiversity and the possible negative consequences of the adoption of certain forms of biotechnology. Amongst environmental experts there is a general consensus that major changes in the preferences and behaviour of consumers and producers are necessary to solve these wicked environmental problems, bringing about a need for system innovations, or so-called industrial transformation.

Industrial transformation research seeks to understand complex society-environment interactions, identify driving forces for change, and explore development trajectories with a significantly lesser burden on the environment. Industrial transformation research is of an integrative and multidisciplinary character, and focuses on systems and systems change. It is based on the assumption that important changes in production and consumption systems will be required in order to meet the needs and aspirations of a growing world population while using environmental resources in a sustainable manner (see Vellinga and Herb, 1999 and Chapter by Geels in this book). 'Transition' or 'transition management' describes how such systems change can take place.

It is obvious that major changes in production and consumption systems will never take place unless they are accompanied by, and even driven by, technological changes. That is why the Dutch government emphasises, in its recent national environmental policy plan (Nationaal Milieubeleidsplan IV (NMP4), 2001), that technological transitions are required in order to arrive at a situation of sustainable development. From the perspective of government intervention, much attention is given in the plan to the possibility of managing transitions towards sustainability.

The national environmental policy plan (NMP4, 2001: section 4.5) uses a very broad concept of transition. It is seen as a long-term societal transformation process, which includes technological, other economic, social, cultural and institutional changes. These changes in the various fields of society interact and strengthen each other. During such periods of transition, policy goals should be formulated and adapted, and policy instruments are to be used in a co-ordinated manner. Transition management plays, in this view, a major role in the planning and co-ordination of the transition process. The national environmental plan thereby describes transition management as a very broad concept too. It requires as key elements process-oriented steering characterised by uncertainty, complexity and interdependence. There is, according to the plan, an explicit role for the government, which should co-ordinate, stimulate, facilitate, steer and maintain.

This article considers technological transitions and the possible role of the government in steering these transitions from the neo-classical economic perspective, and will focus its analysis by using a narrower and more precise concept of transition and transition management. The neo-classical perspective confines the definition of *transition* to a technological transition where an old and less productive technology is gradually replaced by a new, more productive technology. Consequently, *transition management* describes how the government can facilitate such a technological transition. The neo-classical perspective does not consider the interdependence among the technological transition and the cultural and social transitions, in the case of a fundamental system innovation; nor does it provide policy prescriptions on how the government should co-ordinate these interdependent transitions; but it does provide government with insights on options to correct market failures. Moreover, in the neo-classical framework preferences are considered as given, so that it does not endogenise the room for the government to interfere in the process of preference formation. However, the neo-classical look at technological transitions is related to the features of industrial transformation in taking into account the dynamic interactions and mutual interdependencies among the (socio-) economic, the technological and the environmental variables.

As a matter of fact, neo-classical economics has a long-standing tradition of describing and analysing processes of technical change and the possible role of government intervention. The leading principle is that economic subjects behave rationally given their preferences. The next section of this article briefly reviews the foundations of neo-classical economics and welfare theory. It also shows how the environment has been given a proper place in this theoretical perspective. In Section 3 we focus on how technical change is analysed within the neo-classical framework. Section 4 describes why technological lock-ins may occur. The underlying reasons for technological lock-ins may give a hint of the role of the government in promoting a transition. The need for transitions and the scope for government intervention to facilitate transitions are discussed in Section 5. Section 6 takes the example of wind energy to illustrate the role of niches in an early transition process. Finally, Section 7 draws some conclusions.

2. NEO-CLASSICAL ECONOMICS AND THE ENVIRONMENT

Economics studies the production and consumption of commodities, *i.e.* goods and services. In particular, economics is concerned with the efficient use of scarce resources in production and consumption. A resource is called scarce if it is not unlimited (and freely) available. A consequence of this limited availability is that an allocation decision has to be made as to what end *casu quo* for the production or consumption of what good the scarce resource will be used. These decisions are taken by the economic actors, *i.e.* the government and private actors (producers and consumers) in so-called markets. One of the basic starting points of neo-classical economics is that economic agents behave rationally; consumers allocate their budgets in accordance with their preferences such that their utility is maximised, while producers allocate their resources in the production process such that profits are maximised.

Within the neo-classical economics school of thought one of the fields of research is welfare economics. Welfare economics focuses on the issue of the well-being of society. Pareto, who defined the concept of Pareto Efficiency, established the foundations of welfare economics. An allocation is called Pareto Efficient if no person can be made better off without making at least one other person worse off. It can be shown that in an economy where all markets are complete and competitive, the resulting allocation, which is based on individual decisions, will be welfare maximising and Pareto efficient. In such an economy there is no need for government intervention.

In the real world, however, several forms of market failures exist which give rise to inefficient allocations and thus may give cause for government intervention. In the following we will examine four forms of market failures: external effects, absence of property rights, public goods and the difference between private discount rates and social discount rates. Economists talk about an external effect if an allocation decision has an effect (*i.e.* a cost or a benefit) that is external to the agent who is causing the effect by his or her decision. In other words, the decision of one agent can affect the welfare of other agents in the economy, and this effect is not compensated for in the market. One of the underlying causes of an external effect can be the absence of property rights, as a result of which there is no market for the goods at stake.

Another form of market failure arises in the presence of public goods. A public good is a good that is non-rival (consumption by one person does not affect the amount available for others) and non-exclusive (nobody can be excluded from consuming the good). Well-known examples of public goods are defence, jurisdiction and environmental quality. As nobody can be excluded from consuming the good, nobody can be forced to pay for the use of the good, and the so-called 'free rider' problem arises, resulting in a sub-optimal allocation. Finally, a difference between the private discount rate and the social discount rate can result in inefficient market decisions. The discount rate, a concept that is used to compare the value of future money with current money, is built out of two components: time preference and a risk premium. Time preference refers to the fact that we prefer to have something today over having the same thing tomorrow. Besides pure time preference, there is another reason why having an amount of money today is preferable to having the same amount of money tomorrow. There is always the risk of losses on future amounts of money due to inflation or to setbacks in future yields. As the risk depends on the investment for which the money is used, it is obvious that there can be a difference between the social and the private risk premium, resulting in a difference between social and private discount rates. This difference can lead to inefficient market decisions.

The natural environment is a notable example of the existence of market failures, since the use of the environment in consumption and production involves external effects and/or property rights that are not (well) defined. Environmental economics focuses on the role of the natural environment in the economic process as well as on the effects of the economic process on the natural environment. Given the above-described characteristic of the natural environment in terms of a scarce resource whose allocation gives rise to market failures, conceptually the environment fits in a natural way within the neo-classical economic framework. At the same time, however, it is difficult to actually include the natural environment in the neo-classical economic framework sketched above from an operational point of view, as the natural environment has so many dimensions, both in space and in time. At least five different economic aspects of the natural environment should be distinguished:

– Environmental quality as a production factor; *i.e.* the non-extractive use of the environment in production;
– Environmental services as a production factor; *i.e.* the extractive use of the environment in production;

- Environmental quality as an (additional) indicator of economic welfare, which implies inclusion of environmental quality as an argument in the welfare function;
- The influence of abatement activities on environmental quality;
- The regenerative capacities of the environment.

So, the environment plays a role both in consumption (welfare) and production. With respect to welfare, only the stock of the environment plays a role, while with respect to production a distinction can be made between flows and stocks in the specification of the environment as a factor of production. Welfare derived from environmental services is not explicitly mentioned, as this aspect is implicit in production in the case of extractive use (*e.g.* water consumption or recreational services that lead to a degradation of the environment); and in the case of non-extractive use (recreational services that do not lead to a degradation of the environment) it is implicit in the environmental quality indicator in the welfare function. Note that extractive use of the environment in production that has negative effects on welfare — think, for example, of smoke or noise — forms part of the welfare function through the environmental quality indicator (which falls as a consequence of extractive use in production). Furthermore, abatement activities can be regarded as investment in environmental capital because they may improve the state of environment. Finally, self-regenerative capacities can (partly) offset the deterioration of the environment due to the use of environmental resources.

Taking the above-described economic aspects of the natural environment into account, the natural environment can be given a proper and natural place within the neo-classical economics framework. The starting point of the neo-classical framework is that the market mechanism can, under specific conditions, lead to an allocation that maximises social welfare. However, in reality, economic activity can have undesired effects on the natural environment due to the existence of market failures. This, however, does not imply that markets are not suitable as a means to allocate resources in a socially most desirable way. Rather, it implies that the shortcomings of markets have to be taken into account, and that the conditions under which markets operate should be improved or that new markets have to be created. In the context of market failures that have to do with environmental issues, a whole range of policy instruments is available, ranging from taxes, subsidies and tradable permits to direct regulation and voluntary agreements.

To this point, we have presented the concept of efficiency as the leading principle in the framework of thinking of neo-classical economists. In the context of environmental issues, the concept of sustainability or sustainable development is central. According to the Brundlandt report (World Commission on Environment and Development, 1987), 'Sustainable

Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.' Sustainability, which raises questions about the welfare of future generations, can in fact be viewed as a long-term variant of efficiency. In order to be able to analyse the conditions under which sustainable development is possible all the (dynamic) interactions between the environment and the economy as described above have to be taken into account. Thus, dynamic specifications of all the relationships involved should be assessed. In studying the long-term relationship between economy and ecology, technology and the development of new technologies play a crucial role. Within neo-classical economics, the analysis of technological change is studied within the field of growth theory. In the next section we will give an overview of this field of research.

3. TECHNOLOGICAL CHANGE

In neo-classical economics, the analysis of technical change is part of growth theory. Growth theory tries to explain structural developments in the economy, *i.e.* long run developments in the production structure given the preferences and, therefore, is complementary to cyclical analysis. The production function has a key role in models of economic growth. This function describes the production process as a transformation of the production factors as inputs to final production as output. The simple traditional models of economic growth have two production factors as inputs, namely labour and capital. However, in growth models that consider environmental issues as well, a third production factor is included, namely energy, which is usually considered as a practical representation of the broader concept of (the use of) environmental capital.

A production function describes a specific production technology. An increase in one of the production factors may, given the production technology, lead to more output. Hence, economic growth can be the result of an increase in input of production factors. However, for the analysis of technological change it is more relevant to consider the consequences of technical progress as a driving force for economic growth. An improvement in production technology will result in a higher output given the various factor inputs. The reason for such higher production may be an increase in the efficiency of the use of one of these inputs. For instance, given the other factor inputs, when less labour is needed to produce the same amount of output, apparently there has been an increase in the efficiency of the use of labour in the production process, which results in higher labour productivity (inputs of units of labour per unit of output). This type of technical progress is called a labour augmenting technical progress. Similarly, we may have capital-augmenting and/or energy-augmenting technical progress. Yet quite often it occurs that we are unable to ascribe the increase in the efficiency of production to one of the production factors. In that case, we have an increase in total factor productivity (TFP).

Traditional neo-classical models of economic growth do not explain why technical progress occurs. Technical progress is exogenous and, as said by Joan Robinson, given to us as 'manna from heaven by God and the engineers'. Yet, more sophisticated empirical models of the production process make technical progress endogenous by describing it as the result of investments in research and development (R&D), and, in the case of labour augmenting technical progress, as the result of an increase in human capital through learning. These models allow us to analyse the consequences of relative price changes for the production technology and for technical progress. For instance, when the relative price of energy increases as compared to the price of labour, we will see, due to the substitution effect, a decrease in the use of energy and an increase in the use of labour in the production process. It implies an increase in energy productivity and a decrease in labour productivity. Yet, as a secondary effect, more resources in research and development may be devoted to enhancing energy efficiency in production and less to the development of new labour saving technology. In other words, the relative price change, which may be an autonomous change but can also be the deliberate consequence of a green tax policy, induces a change in the bias of technical progress: technical progress becomes more energy-augmenting and less labour-augmenting (see *e.g.* Den Butter and Hofkes, 2001).

Like all models in economics, the production function is a metaphor and a very stylised representation of reality. Extending economic growth models to mimic reality more closely is needed to account for the fact that techniques are incorporated in existing capital goods. The capital goods that are installed some years ago will use an older (and less efficient) technology than new investments that can be added to the capital stock today. It is, however, necessary to use capital goods in the production process for a considerable period of time in order to earn back the investment costs. So one cannot always install the most modern and efficient capital goods and scrap all other ones. That is why in practice it is impossible to adapt the production method immediately to a change in factor prices. This way of modelling production is called 'the vintage approach' because a row of consecutive investments in capital goods is distinguished as separate vintages that build up the capital stock. In the course of time, on the one hand, investments are added as new vintages to the capital stock, whereas on the other hand, old vintages are scrapped when they become unproductive and when investment costs are earned back. In their assumed rational investment behaviour, entrepreneurs reckon with all future relative price changes and are supposed to be able to calculate the time period a vintage has to remain installed in order to earn back the investments' costs. Uncertainty and learning behaviour may complicate this calculation, however.

Especially at the level of the plant or industry, vintage models provide a more elaborate representation of technological change and the adoption of new techniques than simple production functions do. Yet, new vintages of capital goods cannot be installed solely because more efficient techniques have become available or because changes have occurred in relative prices of production factors. Apart from an informational deficiency on the part of the producer, the phenomenon of 'time to build,' or to restructure, may be a reason why, in the case of so called win-win situations, where implementing new techniques can be both more environment-saving and more labour-saving than existing techniques — such new technology is not always immediately installed. So, neo-classical vintage models can explain why it can be rational that win-win situations are not (immediately) exploited by the industry. Moreover, it takes time (and money) to instruct personnel and let them become familiar with the working of a new technology. As we will discuss later, these learning processes play an important role in the path dependency of the implementation of technological innovations and are an important reason for lock-ins of existing techniques.

Indirectly and in due time, however, a change in relative prices will indeed lead to a change in the structure of production where the bias of technical progress is directed towards production factors which have become relatively more expensive. For instance, when the increase in the costs of energy exceeds the rise in wage costs, *e.g.* as a result of policy measures, entrepreneurs will select those new production techniques from the range of possible techniques that yield the highest energy efficiency. Moreover, when selecting which of the old capital goods are to be scrapped, the energy efficiency of the production process will have a greater weight in the decision than labour intensity.

Obviously, only calculations that use empirical models can show whether labour and energy savings were caused by a particular policy or by autonomous variations in factor prices. Moreover, these empirical models can also be used to calculate various scenarios for technological transitions. In such cases, policy measures (*e.g.* shifts of taxes from labour to energy) can be implemented by means of exogenous changes in the prices of energy and labour in the model. Yet alternative scenarios for transitions can also be obtained by a sensitivity analysis on the estimated or calibrated parameter values of the model. Such scenarios may represent the influence of institutional changes (*e.g*. the introduction of a system of tradable emission rights) or of changes in preferences (*e.g*. a greater weighting being given to environmental quality).

Another (and more common) interpretation of sensitivity analysis is that it provides insight into the possible range of future developments given the uncertainty about the parameter values that are used in the model's baseline projection. It should be noted that scenarios based on empirical models differ considerably from the socio-technical scenarios for transitions (see *e.g*. Geels, 2002) that are of a narrative and much broader nature.

What implications do the mechanisms described in the vintage models of economic growth have for environmental policy that aims to reduce energy use or, more broadly, for policy designed to reduce the use of environmental capital, which has to be directed at an increase in energy productivity? Given the available funds for research and development, so that the same amount is invested in the development of new technologies, and, roughly speaking, total factor productivity remains the same, such policy may lead to a relative decrease in labour productivity and/or capital productivity in comparison with the scenario without environmental policy. These changes in productivity will also lead to changes in product prices. This implies that environmentally intensive, 'dirty' products will become more expensive relative to 'clean' products, which use less environment in their production processes. This is because, in general, the possibilities for substitution in the production process will be too small to fully compensate the changes in factor prices.

Hence, in general, the products of sectors of industry with 'dirty' production methods will become more expensive in comparison to products from sectors that use clean technology. So, to some extent, the aim of the policy, namely a decrease in the use of the environment as a production factor compared to current trends, will be reached by means of a relative shrinking of the 'dirty' sectors and a relative growth of the clean sectors. This can be seen as a consequence of a general policy directed at internalising the negative externalities of environmental use in production. Therefore, in order to achieve a shift in the sectoral structure of production that leads to less damage to the environment, there is no need for (domestic) environmental policy to take specific measures with respect to 'dirty' sectors of industry.

The description above relates to the influence of environmental policy on technological change. From the neo-classical perspective, the reason for conducting environmental policy, in this case by changing the relative prices of factor inputs, is that the production using energy (or the environment more generally) as an input brings about negative externalities. These negative externalities imply a market failure, which the government has to correct in order to enhance social welfare. In this case, we assume a broad concept of social welfare with environmental quality as one of its elements (see also Den Butter and Hofkes, 1995). The policy prescription is to internalise the externality so that the users pay a socially optimal price for the use of energy (or the environment).

On the other hand, modern neo-classical theory of economic growth explains that, in the case of the development of new techniques and in the adoption of new techniques in production, positive externalities may occur. These externalities are the main reason why governments should introduce technology policy in order to enhance social welfare. In this case, market failures relate to the fact that the revenues of investment in R&D will almost never completely accrue to those who have financed the research. Research, and the implementation and adoption of technical innovations, almost always bring about positive spill-over effects to others, who may in turn use the experience in further research ('standing on shoulders') or in their own production process (taking advantage of others' learning). Technological knowledge has, in part, the character of a non-rival, public good. This is why, when investment decisions are completely left to the market, it generally results in underinvestment in R&D. It is true that the government may, by means of patents and so on, give complete property rights of the technology knowledge to those who have invested in the new knowledge. Yet, from the perspective of social welfare, such a situation is not optimal because in that case others cannot apply that knowledge and use it to further develop the technology. This is why technology policy aims to avoid under-investment in technological knowledge and tries to promote the use and diffusion of this knowledge. So we see that, from the neo-classical perspective, a good analysis of these types of market failure is essential for sound economic policy. This applies to how both environmental policy and technology policy affect technological change.

The neo-classical growth models described above are characterised by a production function with diminishing returns to the accumulation of capital, and constant returns in labour and reproducible capital together. In such a model, only continued technological progress can sustain a positive growth rate of output in the long run. Without technological progress the effects of diminishing returns eventually cause economic growth to cease, and the only feasible steady-state rate of growth that can result is a zero rate. New growth theorists have tackled this unsatisfactory property of neo-classical growth theory by endogenising the long-run rate of economic growth.

Endogenous growth can be modelled in different ways. In the late 'eighties, the first endogenous growth models appeared (Lucas, 1988; Rebelo, 1991; Romer, 1986). In Rebelo's so-called AK-model (Rebelo, 1991), endogenous growth arises because of constant returns to the reproducible factors. In this model growth is unintentional but arises as a side product of investment. Romer (1986) extends the neo-classical growth theory by accounting for production externalities. These production externalities are a consequence of knowledge spillovers in the process of human capital accumulation arising from learning by doing. In the Lucas-model (Lucas, 1988) growth arises from intentional investment in human capital. In this model, workers have to decide how much of their time they want to spend on producing goods and how much they use for learning activities. By learning, workers invest in their human capital, which leads to higher real wages.

These new developments in growth theory have also contributed to the interest in integrating the environment in economic models. In the early 'nineties, the first endogenous growth models in which the environment plays a role appeared. Gradus and Smulders (1993) analyse two endogenous growth models that incorporate the environment. Their first model is an extension of the AK-model, and their second model builds on Lucas (1988). Bovenberg and Smulders (1995) take a step further and develop a growth model with endogenous pollution-saving technology, which takes the form of knowledge of an efficient use of renewable resources. Hofkes (1996) builds on the Bovenberg and Smulders model and develops a two-sector growth model that also allows for abatement activities. Yet these models of endogenous growth do not provide much information on technological transitions and their underlying causes.

4. TECHNOLOGICAL LOCK-INS

The new growth theory that was developed in the 1990s studied the issue of sustainability, *i.e.* the question of whether sustained economic growth is compatible with conservation of the environment. The conclusion emerged that maintaining environmental quality and economic growth can go together if a steady flow of technological innovations increases the efficiency of resource use (Aghion and Howitt, 1998). Yet these new or endogenous growth models, as we discussed in Section 3, do not make a distinction between clean and dirty production technologies. If one wants to study technological transitions from dirty to clean technologies, attention has to be paid to technological diversity.

The focus on technological diversity is one of the major elements in evolutionary models. Evolutionary models typically describe a diverse set of technologies,[21] a diversification mechanism broadening the set, such as the arrival of random innovations, and a selection mechanism for the reproduction of specific technologies. The continuous diversification and selection mechanisms cause a drift (see also Chapter by van den Bergh in this book) in the characteristics of the current technology set. Those technologies that are most successful given the economic environment, the institutions, and policy regulations, are the 'fittest' and will then be reproduced. Within the context of evolutionary models, technological regimes, technological transitions, and technological lock-ins play a central role (see *e.g*. Dosi, 1982; Nelson and Winter, 1982; Arthur, 1989). Following Street and Miles (1996), a technological regime refers to 'the whole complex of scientific knowledge, engineering practices, process technologies, infrastructure, product characteristics, skills and procedures which make up the totality of a technology.' (Street and Miles, 1996: 413).

The concept of technological regimes can also be applied in the framework of the new growth theory. In the context of this framework, we will use the term 'technology clusters' instead of 'technological regimes' to indicate that the analysis in the framework of (new) growth theory takes place at a more abstract, less detailed, level. In neo-classical economic terms, the process of technology selection is characterised by increasing returns to scale and path-dependence. Typically, technology clusters, such as the fossil-fuel energy system, have their own infrastructure, and this leads to a specialisation in the following way: Innovations that improve on dominant technologies, which are technologies with a substantial market share, generate substantial profit flows, and thereby, these innovations are very valuable to the owners of the innovations, the innovators. This mechanism generates a continuous flow of innovations, which is essential to maintain high productivity levels, low production costs, and substantial market shares.

On the other hand, innovations in technologies with minor market shares are less valuable, and thus the incentive to improve on the technology is less powerful so the minor technology maintains a low productivity level, high costs, and a minor market share. In short, the positive feedback from market shares to innovations, to productivity, to market shares, strengthens the position of existing dominant technology clusters, and cuts the competitiveness of alternative, new technologies. This phenomenon is known as increasing returns to scale, and it leads to path dependence. The economy will specialise in technologies typical of the dominant cluster. This phenomenon of specialisation can in the end lead to a situation of lock-in.

[21] This technological variety may be embodied in firms, sectors or countries. For example, in (Nelson and Winter, 1982), the set consists of firms that possess different capabilities, procedures, and decision rules.

Increasing returns can be classified into three broad types: network externalities, learning effects, and economies of scale. Network externalities refer to the fact that the existence of networks (interrelations) between technologies, infrastructure and users of technologies can give rise to positive externalities, as the networks become more valuable as they grow larger. An example is telephone networks that become more valuable the more subscribers they have, since more people can be reached through them. Learning effects occur if, as a consequence of knowledge accumulation, the costs of using a technology decrease (and/or the performance of a technology improves). Finally, economies of scale can arise if, as a consequence of high fixed costs, the costs per unit decrease if production increases. In all cases, a mechanism may come into force where increasing returns lead to specialisation, and eventually to a situation of lock-in.

Gerlagh and Hofkes (2002) show that in an economy which takes into account environmental quality and where spillovers occur, three different types of externalities may exist: an investment externality, a 'choice-of-technology' externality and an environmental externality. Investment externalities result from the existence of spillovers between firms (See Section 3). This leads to the investment externality situation where investments fall short of the social optimum, which is in fact equivalent to the network externalities discussed above. The 'choice of technology' externality has to do with the fact that, due to path dependency, the distribution of investments over different technology clusters may be sub-optimal from a social welfare point of view. Finally, the environmental externality arises from the fact that there is no proper market for the environment. It is important to distinguish these three types of externalities, as only taking away the environmental externality does not imply that situations of lock-in will no longer occur. In Section 5 we will look at government policies with respect to the different types of externalities, and discuss the question of how government intervention may induce an escape from an undesired situation of lock-in.

We complete this section by looking at an example of technological lock-in. One of the most discussed and pressing examples of technological lock-in is the lock-in of industrial economies into fossil fuel-based technological systems. Despite the availability of carbon-saving technologies that have environmental and economic advantages, carbon-based energy technologies are still being widely applied. There appear to be barriers to the diffusion and adoption of the alternative carbon-saving technologies. These barriers can, at the micro-level, be explained by myopic micro-economic decision-making. Above that, at the macro-level there are forces that create systematic barriers to the adoption of carbon-saving technologies. These forces can be understood in terms of path-dependence, which comes about as a result of positive feedbacks into the economy (increasing returns). As a consequence, dominant designs are continuously being refined and firms incrementally develop their know-how. Examples of inferior technologies becoming locked-in as dominant designs are the QWERTY keyboard and the VHS video tape technology.

5. TRANSITIONS AND GOVERNMENT INTERVENTION

In principle, neo-classical economics describes technology transitions as processes of gradual technical progress, which is the eventual result of rational behaviour. Three consecutive steps can be distinguished when entrepreneurs make investment decisions in technological development. The first choice is to decide what part of the available factor inputs, labour in particular, is utilised for actual production, and what part is assigned to investments in R&D that leads to increases in technology capital through the design and implementation of a more efficient production technology. Important in this decision is the trade-off between foregone production now, when investing in the development of a new technology, and expected future increases in production, when the newly developed technology becomes operational. The second decision is about the type of these investments in R&D. Here the entrepreneur has to decide about the bias of technical progress. Should research be directed at the development of a more energy-saving technical progress, or will the focus be on enhancing the efficiency of labour in production? This choice determines the type of vintages that can be installed in future. The third decision relates to new capital investments, namely whether new vintages are installed to improve on existing technologies or whether the new capital investments use a new technology. The latter case would represent the start of a technological transition. According to neo-classical economics, relative prices and expectations about relative prices, uncertainty, and the costs of learning processes are the main determinants of decisions on these three choices.

As noted in Section 3, government policy will interfere with these choices in so far as the policy aims at correcting market failures. We have seen that environmental policy relates to negative externalities in the use of energy in production, and technology policy relates to positive externalities because of spillovers in the design and adoption of technology capital. Both types of policies may, through the mechanisms described above, contribute to technological transitions. However, neo-classical theory does not leave much scope for additional transition management by the government. In fact, if the government is to promote technological transitions, it must have good reasons to do so. An essential prerequisite for transition management is that production in a broad sense has to be trapped in a technological lock-in, which, from a long-run perspective is considered unfavourable. In other words: for transition management to be successful it is necessary to know both the reasons that have caused technological lock-in (see the previous section) and to have a clear indication that the lock-in is socially sub optimal in the long-run. These are harsh conditions that limit the scope of transition management much more than the broad concept in the national environmental policy plan (NMP4, 2001), and in the proposals for transition management following this plan (see *e.g.* Aubert *et al.*, 2001, RMNO, 2003). From the neo-classical perspective the rules for policy intervention are also stricter than suggested by evolutionary economics (see also chapter by van den Bergh *et al.*, in this book).

A major question when the government considers intervention in a dominant technology is whether there are alternative technologies that, for some reason, did not succeed in becoming dominant. It seems that the government should be very cautious in promoting the transition to such existing alternatives. An example is the promotion of public transport at the cost of private transport. Apparently both technologies co-exist and there is no reason, other than internalising the negative externalities of private transport, for the government to favour a shift to public transport. Both technologies co-exist because they are imperfect substitutes and even, to some extent, complementary to each other.

From the neo-classical perspective, a reason for additional government intervention in promoting technological change can be that initiating the development of a complete new technology is very costly because, at that early stage, it is very uncertain whether it will become the dominant single technology where the investment costs are earned back. In fact, it is the imperfect working of the capital market that provides a reason for such government intervention. Here the role of transition management is to facilitate the development of new technologies in niches where they are, in an initial period, protected from harsh competition. Yet, after this period of variation facilitated by the government comes a period of selection. The scope for the government to interfere in this selection process is very limited. The government, by no means has a lead in information on which of the alternative new technologies will yield the highest social welfare in a technological transition. Therefore, the government should not try to pick winners. The government, however, may interfere when letting the market do its work seems to lead to a suboptimal technology (but, again, who decides what is suboptimal?). Government intervention may also be needed when, due to network externalities, the economy gets trapped in an unwarranted lock-in of a technological monopoly, or, on the contrary, in a technology split that is socially suboptimal because network externalities are not fully exploited. An example of the latter is the simultaneous introduction of the 'chipper' and the 'chipknip' as two competing forms of plastic money by two bank consortia in The Netherlands. During the co-existence of both technologies, hardly any transition took place to this new payment technology.

All in all, from the neo-classical perspective it seems that the traditional policy instruments of environmental policy and of technology policy still constitute the basic tools in transition management. Yet when there is a clear indication that an escape from an existing technology is needed, it can be important to put the existing system under pressure by means of levies and regulation. This makes the old system more expensive and enhances the incentives for the development of, and the transition to, a new system. Such transition policy requires both a solid knowledge of the reasons for the lock-in and of the market failures that prevent adoption of a new technology in a socially optimal way. However, unlike evolutionary economics, no further policy prescriptions can be given to the shape and timing of stimulating transition trajectories. Moreover, there is another reason why the policy of making the old system more expensive is to be preferred to a policy of general subsidies for the development of new technologies. Subsidies may cause early adoption of a new technology, whereas, with the benefit of hindsight, it would have been better to wait and adopt a more efficient technology later. As a matter of fact, general subsidies for development and adoption of new technologies (or to improve on existing technologies) bring about high 'deadweight' losses, *i.e.* a large number of entrepreneurs would have developed or adopted the new technology without subsidies.

6. TRANSITION TO WIND ENERGY: AN EXAMPLE

An obvious way to achieve more sustainable use of energy would be a transition from fossil fuel-based production methods to wind as a means of energy production. Although the use of wind as a source of energy has a long tradition, the technology of large-scale production of electricity by means of wind turbines has only recently gathered (new) momentum. Development of wind turbine technology is ongoing, especially with respect to electricity production, and various routes are still open. Wind turbine technology can thus be regarded as an example of technological transition at an early stage, where various alternative technologies still co-exist and the selection of a dominant technology has not yet taken place. In principle, two different roads are open for the adoption of wind technology: namely, production by relatively small windmills on the premises of individuals, farmers, in most cases, and on a larger scale in windmill parks owned by major electricity-producing companies.

Klaassen *et al.* (2003) report on how government policy, with respect to subsidising the development of wind turbine technology and the adoption of that technology, has been different in Denmark, Germany and the United Kingdom. Differences in policy have resulted in different outcomes with respect to the extent of wind energy production in these countries; so the case can be seen as a kind of natural experiment in transition management, although neo-classical economists would look at it from a different perspective, seeing it as a lesson in what incentives government can use to promote the development and adoption of a new technology. Learning curves and their exploitation play a major role in the design of government policy to speed up a warranted technological transition.

The Danish policy to promote the development and use of wind turbines for electricity production has been most successful. Klaassen *et al.* (2003) conclude that in Denmark, R&D as well as demonstration projects, in conjunction with investment subsidies, favoured the development of reliable small wind turbines. In that country, the careful balance and timing of R&D and procurement support have been important to promote both innovation and diffusion of wind energy. Denmark started to promote wind energy in the mid 1970s. In 1991, wind turbines provided around 3% of Danish electricity consumption. It appears that the success of the Danish policy can be ascribed both to an early start in promoting these developments ('first movers' advantage') and to good insights into the learning processes so that the adoption of reliable windmills by farmers on a small scale was favoured. The European Commission (1997) reported another aspect that may have contributed to this Danish success: the first large market for the modern wind industry was California, USA, in the early 1980s. The growth of this market, a good example of an early niche for a new technology, stimulated the development of wind technology in many other countries. In the years from 1986-1990, the market in California declined, causing major financial difficulties in the wind industry. Many companies went bankrupt, but the simple Danish, 3-bladed stall-regulated design survived and was even up-scaled to provide more cost-effective units. This early selection process thus favoured Danish windmill technology.

By contrast, German R&D programs that started also in the 1970s, but aimed at developing large-scale wind energy production, failed. Yet the development of small wind turbines, where various subsidies provided an incentive for product and process innovation, has been rather successful in Germany, although overlapping subsidies might have resulted in efficiency losses. Moreover, due to knowledge spillovers, small German windmill manufacturers were able to benefit from Danish expertise. According to Klaassen *et al.*, the UK has been least successful in promoting wind energy. Here, support for renewable energy only started in 1989 with the passing of the electricity Act. R&D expenditures were insufficiently geared towards the type of turbines being installed. The UK subsidy scheme thus contributed to driving down the costs but not much capacity has been installed.

The example of wind energy shows that, with the benefit of hindsight, part of the developments can be explained by means of neo-classical economic theory. It is documented how price incentives (through various types of subsidies) influenced the adoption of new technologies, and how learning curves played a crucial role. Yet more sophisticated neo-classical models should be developed to explain more of the transition to wind energy. More attention should be paid to the total adoption costs of the alternative new technologies. These consist not only of learning costs and investment costs, but depend also on the societal preferences and acceptance with respect to the various types of windmills. It appears that large-scale windmill parks may bring about more societal costs than small windmills used by individual farmers, due to the impact on the landscape. However, such preferences may eventually change. Environmental valuation methods could give more insights into these indirect societal costs.

7. CONCLUSION

Neo-classical economics has a long-standing tradition with describing processes of technological change. This perspective is very much related to what environmental policy-makers nowadays call 'technological transitions.' Therefore, neo-classical economics offers an excellent methodological framework for the design and evaluation of policy prescriptions with respect to technological transitions and transition management. The arguments are based on formal models of production processes where, through the market economy, price incentives lead to the development, adoption and use of socially optimal production technologies. Changes in preferences, *e.g.* towards a higher weighting of the environment in the welfare function, result in changes in price incentives which promote the gradual adaptation of existing equipment to the technology which is optimal under the new preferences. Ideally, in their R&D investments, entrepreneurs anticipate these preference changes so that producers can avail themselves of the new technologies in due course.

In this formal neo-classical theory, the role of the government is limited. Government intervention is needed in the case of market failures, *i.e.* when rational behaviour of individual consumers and producers does not lead to a socially optimal outcome. In most cases (positive and negative) externalities will be the reason for market failure. The appropriate policy is to correct these market failures by internalising the externalities. There are various ways to do so, but from the neo-classical economics perspective it is essential that government intervention should be based on an extensive analysis of the types of market failures. Here the favoured choice of government intervention is through prices. Yet when the markets do not work perfectly, *e.g.* the capital market fails to finance highly risky R&D investments in new technologies, other types of government intervention may be justified.

To justify such government intervention, policy-makers should always see to it that the benefits of repairing market failures outweigh the costs of government intervention. Therefore, the government should be very cautious when conducting transition management that goes beyond traditional environmental policy to correct the negative environmental externalities, as well as traditional technology policy, which copes with positive externalities caused by knowledge spillovers in R&D and new technology adoption. Here, it appears that for the promotion of technological change, more emphasis is needed on adoption as compared with technological innovation (see *e.g.* Mulder, 2003).

When there is general consensus that an escape from a technological lock-in is needed and that only a fundamental system innovation can resolve a ‘wicked’ environmental problem, a solid analysis should be made of the causes of the lock-in. These causes relate to the path dependence and the increasing returns with respect to adoption and use of dominant technologies, such as the fossil fuel-based technological systems of industrial economies. In that case, it is the subtle interaction between the design of new technologies and the learning processes with respect to implementing these new technologies about which the government should collect information in order to facilitate the escape from a technological lock-in.

In sum, in the neo-classical view of industrial transformation and transition management, the emphasis is on the co-ordination between environmental and technology policy, where the government should reckon that diversification of new technologies can be hindered by capital market imperfections and that societal costs with respect to environmental preferences can play a major role in the adoption of new technologies. The scope of transition management is limited, however, in the sense that final decisions about the development and adoption of new technologies should be left to entrepreneurs.

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Chapter 9

MULTI-LEVEL PERSPECTIVE ON SYSTEM INNOVATION: RELEVANCE FOR INDUSTRIAL TRANSFORMATION

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Abstract: This chapter describes how insights from several different disciplines can be integrated in a multi-level perspective, so as to contribute to an encompassing understanding of the dynamics of system innovation. The chapter also argues that a range of different policy instruments is needed to stimulate system innovations, and positions them in different phases and on different levels. Interesting topics for further research are also identified.

Key words: system innovation, multi-level perspective, policy implications, research agenda

1. INTRODUCTION

The aim of this paper is to present an integrative conceptual perspective on the dynamics of system innovations. An understanding of such dynamics is important, because system innovations have recently received much attention in environmental sustainability debates. Modern societies face structural problems in several sectors. Agriculture, for instance, suffers from the consequences of (over-) intensive production systems, such as manure problems, ammonia emissions, and diseases like Bovine Spongiform

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Xander Olshoorn and Anna J. Wieczorek, Understanding Industrial Transformation: Views from Different Disciplines 163–186.

Encephalopathy (BSE[22]) and 'Foot & Mouth'. In the energy sector there are problems such as oil dependency, reliability, and CO_2 and NO_x emissions. In the transport system there are problems of congestion, energy use, and CO_2 emissions and air pollution (particulate matter, NO_x). These problems are deeply rooted in societal structures and activities. To solve them the Industrial Transformation (IT) project of the International Human Dimension Programme (IHDP) argues that system changes are needed (Vellinga and Herb, 1999). Several other recent contributions to the sustainability debate also propose widening the analytical focus from cleaner artefacts to cleaner systems (*e.g*. Unruh, 2000; Jacobsson and Johnson, 2000; Berkhout, 2002).

In the Dutch fourth National Environmental Policy Plan (VROM, 2001), the need for system changes has been rephrased as a need for transitions and system innovations. Substantial improvements in environmental efficiency (factor 2) may still be possible with incremental innovation and system optimisation. But large jumps in environmental efficiency (factor 10) may require system innovations and transitions. The promise of system innovations is represented in Figure 1.

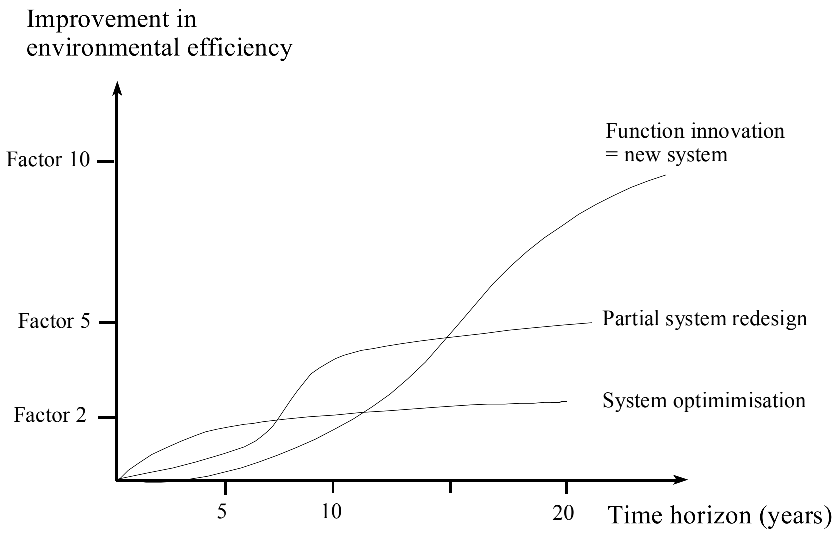

Figure 1. Environmental efficiency and system innovation (Weterings et al., 1997: 18)

System innovations are not merely about changes in technical products, but also about policy, user practices, infrastructure, industry structures and

[22] Bovine Spongiform Encephalopathy (BSE) or mad cow disease.

symbolic meaning, *etc*. To highlight that social and technical aspects are strongly interlinked, I propose to rephrase system innovations as changes from one socio-technical system to another. Figure 2 gives an example of a socio-technical system in the transport domain.

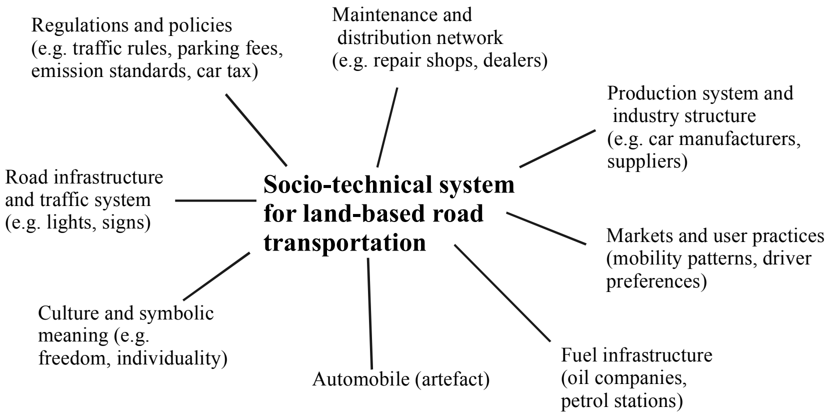

Figure 2. Illustration of the socio-technical transport system

The elements of socio-technical systems do not function on their own, but are actively created and maintained by human actors embedded in social groups. Figure 3 presents a stylised representation of some of the relevant groups in modern western societies.

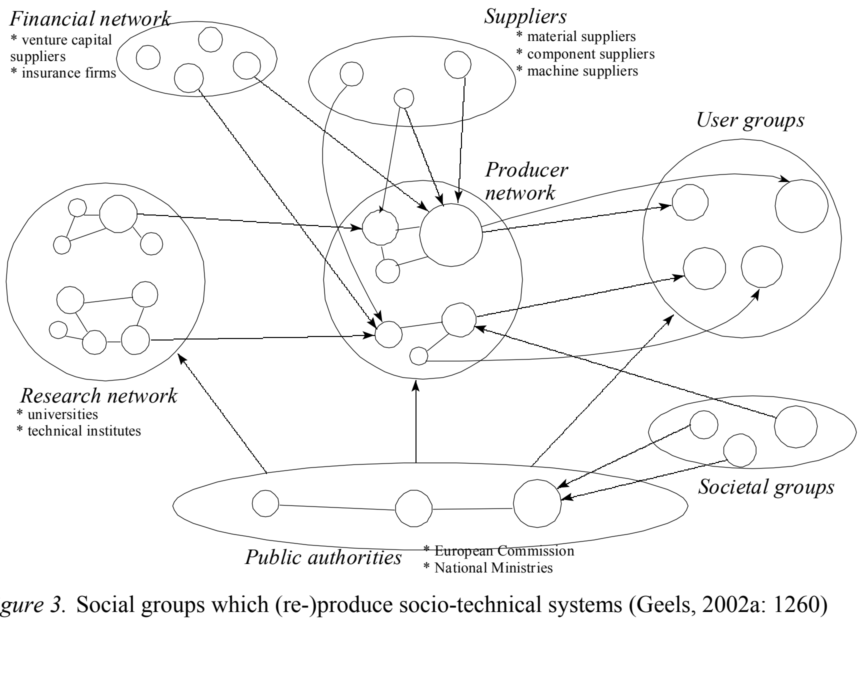

Figure 3. Social groups which (re-)produce socio-technical systems (Geels, 2002a: 1260)

System innovations can be delineated as having the following characteristics:

- They involve co-evolution of a number of related elements;
- They involve changes in the supply side (*e.g.* technology, knowledge, industry structures) *and* the demand side (user preferences, cultural meaning, infrastructure);
- They involve a wide range of actors;
- They are long-term processes (evolving over decades). This presents challenges for effective and consistent policy interventions over political timescales, and also for the analysis of ongoing transitions under policy interventions.

Because of the 'sustainability promise,' there is increasing interest in transitions and system innovations from policy-makers, NGOs, large firms and others. The Stockholm Environment Institute, for instance, published a book on the '*Great Transition'* (Raskin *et al.*, 2002). The American National Research Council (NRC, 1999) and the Dutch Research Council NWO have made transitions part of their research portfolio, and the IHDP bundles research across the world by funding a science programme on industrial transformation.

Although there is apparent interest from policy makers in system innovations, there is little systematic knowledge about transitions from one system to another. The main question this chapter aims to answer is: how do system innovations come about? As an answer to this question, the chapter describes a so-called multi-level perspective, in Section 3. This perspective was built on insights from other disciplines. To indicate these backgrounds, some of the building blocks are described in Section 2. Unfortunately, there is not enough space to describe precisely how these building blocks add up to the multi-level perspective (see Geels, 2004), but I will make brief references to the building blocks in Section 3. There is also insufficient space to give empirical examples, although references are provided to empirical work. The paper does address policy suggestions from this perspective (Section 4) and suggests a research agenda (Section 5).

2. SOME DISCIPLINARY BUILDING BLOCKS

Interesting insights can be found in a range of disciplines (see other chapters in this book). Particular elements from the literature can be used as building blocks for a more integrative perspective. This section briefly describes some of these building blocks. The description is eclectic and cannot do justice to all that has happened in different disciplines.

Sociology of technology

Sociology of technology highlights the notion that technologies are not simply there, but are actively constructed by human actors and social groups. Scholars in this discipline focus mainly on emerging technologies. Early in the development of a technology, there is much flux and uncertainty about precise technical characteristics, functional dimensions, markets and user preferences. Gradually, these dimensions become aligned and stabilise, leading to dominant designs and normal markets. Technologies, markets, user preferences, *etc*., are thus seen as the outcome of articulation processes, learning and interaction. Within this discipline there are several research streams with different point of emphasis. I will provide some brief descriptions.

In the social construction of technology approach (SCOT) the focus is on socio-cognitive processes, *i.e*., on giving meaning and interpreting in social groups (Pinch and Bijker, 1987; Bijker, 1995). The main aim of the SCOT approach is to understand the form and function of new technologies. Why do new technologies stabilise into a particular form, and how are they used? To answer this question, the SCOT approach studies the ideas and discourse about technological artefacts (*e.g*. problem agendas, search heuristics, guiding principles) in the social groups that are involved in the development and use of those technological artefacts, *e.g*. engineers, users, policy makers, social groups, *etc*. There is variation in the sense that different groups have different ideas and propose different solutions, but gradually one idea and solution become dominant, leading to consensus about the dominant meaning of an artefact. Selection is thus seen as a socio-cognitive process (closure and stabilisation of one interpretation in social groups).

In the socio-technical approaches of large technical systems (LTS) and actor-network theory (ANT), the focus is on linkages in and around the emerging technology. In both perspectives the dynamic is that heterogeneous elements are gradually linked together, emphasising co-evolution.

In LTS-research the focus is on (somewhat heroic) system-builders, who weave heterogeneous elements into a working system (Hughes, 1987; 1994; Mayntz and Hughes, 1988; Staudenmaier, 1989). System-builders such as Edison are 'heterogeneous engineers.' These engineers work not only on physical materials, but also on people, texts, devices, city councils, economics *etc*. Hughes (1987) coined the term 'seamless web' to indicate the heterogeneous character of LTS. In the early phases, the web is fragile, requiring system-builders to put in much work to uphold it. For example, as the electricity network grows and stabilises, it gains 'momentum' and begins to have coordinating effects (Hughes, 1994).

The perspective of socio-technical linkages is most consistently developed in ANT (Latour, 1987; 1991; Callon, 1991). New technologies emerge from a start as heterogeneous configurations. In the early phase of a new technology, the network consists of only a few elements and linkages. Innovation is about the accumulation of elements and linking them together in a working configuration. To achieve this, actors try to 'enrol' others, thus widening the network. They also try to 'translate' others, *i.e.*, assign them to particular roles and manipulate them into positions that suit their own purposes. In the ANT approach, enrolment and translation involve both human and non-human actors, leading to deep ontological debates that go beyond the purpose of this chapter. As the network is expanded and more elements are tied together, a technology 'becomes more real.' Diffusion is also a process of creating socio-technical linkages. The diffusion of an artefact across time and space needs to be accompanied by an expansion of linkages within which the artefact can function, *e.g.* test apparatus, spare parts, maintenance networks, and infrastructure. 'Thousands of people are at work, hundreds of thousands of new actors are mobilised' (Latour, 1987: 135).

A fourth stream in the sociology of technology highlights the importance of expectations and strategic visions of the future. Shared ideas about the future guide the direction of search activities. These visions can also be used by product champions as a strategic resource to attract attention (and funding) from other actors (Van Lente, 1993; Brown and Michael, 2003).

A fifth stream is formed by domestication studies. These look more closely at the demand for new technologies (*e.g.* products), arguing that the use of a technology involves more than simple adoption. New technologies have to be 'tamed' to fit into concrete routines and application contexts (including existing artefacts). Domestication involves symbolic and practical work, in which users integrate the artefact in their user practices and cognitive work, which includes learning about the artefact (Lie and Sørensen, 1996). This means that consumption and adoption are themselves acts of innovation. As users become acquainted with new artefacts, they may develop new user routines and new functionalities.

Business studies

In recent years, there has been increasing interest from business studies in radical product innovations, particularly because it was found that existing firms often 'wiped out' of the market because they did not foresee the next technological wave (Christensen, 1997). Some recent business studies emphasise that the co-evolution of technology and markets is a highly uncertain process, marked by setbacks and surprises, and with no guarantee of success (*e.g*. Lynn *et al*, 1996; Leonard-Barton, 1995). Firms that successfully navigated radical innovations engaged in various market experiments with technical prototypes during the early phases of development. Probing and learning was initially more important than immediate success.

These companies developed their products by probing initial markets with early versions of the products, learning from the probes, and probing again. In effect, they ran a series of market experiments, introducing prototypes into a variety of market segments (Lynn *et al.*, 1996: 15).

Evolutionary economics

Evolutionary economics (EE) is a very wide field, which I cannot do justice to here (see the chapter by Van den Bergh in this book). Many studies have a primary focus on firms and economic development. Attention on technology is then secondary and is only used to help explain economic performance. Those studies have limited relevance for my research question. But other EE studies take technological change as a focus in its own right. For instance, Nelson and Winter (1982) and Dosi (1982) consider seriously engineers' and designers' activities. Nelson and Winter (1982) argue that human beings use cognitive frameworks and routines to make sense of the world and guide activities. The search activities of engineers are guided by cognitive heuristics; that is, instead of exhaustively searching in all possible directions, engineers and R&D managers typically expect to find better results in certain directions. In so far as firms differ in their organisational and cognitive routines, there is variation in their technological search directions and the resulting products. The products (and the underlying routines and the firms which carry them) are selected in markets. Successful products (and firms) continue their routines, while less successful firms die out. When different firms share particular routines, these routines make up a *technological regime*, which leads to technical trajectories on a sectoral level. Technological regimes create stability because they provide a direction for incremental technical development.

Institutional theory

Institutional approaches highlight the point that human actors are embedded in social groups, and that the activities of social groups are coordinated by institutions. Institutions are often confused with (public) organisations (Scott, 1995). To avoid this confusion, the general concept of 'rules' also tends to be used. The function of institutions or rules is to guide (but not determine) the perceptions and activities of actors. Shared rules thus provide co-ordination and stability. Following Scott (1995), one can distinguish three kinds of rules: regulative, normative and cognitive. The *regulative* dimension refers to explicit, formal rules, *e.g.* government regulations, which structure the economic process through rewards, incentive structures and sanctions. Examples are property rights, contracts, patent laws, tax structures, trade laws and legal systems. These rules are often highlighted by institutional economists (*e.g.* Hodgson, 1998; North, 1990). *Normative* rules are often highlighted by traditional sociologists (*e.g.* Parsons, 1937). These rules confer values, norms, role expectations, duties, rights and responsibilities. Sociologists argue that such rules are internalised through socialisation processes. *Cognitive* rules constitute the perception of reality and the cognitive frames through which meaning is made. Social and cognitive psychologists have focused on the limited cognitive capacities of human beings and how individuals use schemas, frames, cognitive frameworks or belief systems to select and process information. Evolutionary economists and sociologists of technology have highlighted cognitive routines, search heuristics, exemplars, technological paradigms and the technological frames of engineers in firms and technical communities (see above).

Rules do not exist as single autonomous entities. Instead, they are linked together and organised into social rule *systems* or rule regimes (Burns and Flam, 1987). Regimes are thus semi-coherent sets of rules that are linked together, and it is difficult to change one rule without altering others. The alignment among rules gives a regime stability and ‘strength’ to coordinate activities.

In this section some interesting insights from different disciplines have been briefly discussed. The next section aims to describe an overarching conceptual perspective that combines or situates these insights with regard to each other.

3. A MULTI-LEVEL PERSPECTIVE ON SYSTEM INNOVATIONS

Both evolutionary economists and institutional theorists argue that socio-technical systems are stabilised by regimes that coordinate the activities of actors and social groups. This stabilising force creates inertia, lock-in and path dependence in existing systems. So it is an intriguing question how transitions to a new system take place.

An answer to this question is provided by the multi-level perspective (MLP) (Kemp, 1994; Schot *et al.*, 1994; Rip and Kemp, 1998; Kemp, *et al.*, 2001; Geels, 2002a; 2002b). The MLP distinguishes three levels: meso, micro and macro, which are not ontological descriptions of 'reality,' but analytical and heuristic concepts to understand system innovations.

The *meso-level* is formed by *socio-technical regimes*. This concept builds on Nelson and Winter's (1982) 'technological regimes', but is wider in two respects. First, while Nelson and Winter refer to cognitive routines, the MLP regime concept refers to the wider category of 'rules':

A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures (Rip and Kemp, 1998: 340).

While the cognitive routines of Nelson and Winter are embedded in the practices and minds of engineers, regime-rules are embedded more widely. Second, socio-technical regimes not only refer to the social group of engineers and production firms, but also to other social groups. Socio-technical systems are actively created and maintained by several social groups (see above). Each of these social groups has its own distinctive features and its own 'selection' environment and therefore each has relative autonomy. At the same time, the groups are also interdependent and interact with each other. Interdependence and linkage between sub-systems occurs because activities of social groups are coordinated and aligned with each other. This is represented with the concept of socio-technical regimes. By providing orientation and co-ordination to the activities of relevant actor groups, socio-technical regimes account for the 'dynamic stability' of socio-technical systems. It is dynamic because innovation still occurs, but it is stable because innovations are of an incremental nature, going in predictable directions, leading to 'technical trajectories.' In evolutionary terms, socio-technical regimes function as a selection and retention mechanism. The rules in socio-technical regimes provide stability by guiding the perceptions and actions of actors. Rules can thus be characterised as the 'deep structure' or 'grammar' of socio-technical systems. In a similar fashion, Nelson and Winter (1982: 134) referred to routines as 'genes' of technological development.

The *micro-level* is formed by *technological niches*, the locus for radical innovations ('variation'). Because the performance of radical novelties is initially low, they emerge in 'protected spaces' to shield them from mainstream market selection. Niches thus act as 'incubation rooms' for radical novelties (Schot, 1998). Protection may occur in different forms. One form is within companies, *e.g.* as strategic R&D investments. Governments may add to the protection through R&D subsidies. Another form of protection is through subsidised real-life projects or experiments. This means stepping out from the laboratory into the wider world. These experiments involve a wide range of actors, *e.g*. firms, users, suppliers, universities, local and national authorities, and funding agencies. A third kind of protection is provided by special market niches, with special-performance selection criteria.

Niches are locations where it is possible to deviate from the rules in the existing regime. Hence, the emergence of new paths has been described as a 'process of mindful deviation' (Garud and Karnøe, 2001), and niches provide the locus for this process. This means that rules in technological niches are not as articulated or clear-cut. There may be uncertainty about technical design rules, user preferences or infrastructure requirements, *etc*. Niches provide space to learn about these dimensions. Insights from the sociology of technology and business studies are relevant here, *e.g*. experimentation, learning on many dimensions, interactions between multiple social groups, negotiations about meanings and interpretation. Niches provide space to build the social networks that support innovations. Product champions try to build constituencies around new innovations (Molina, 1995), trying to expand the network of linkages in which these innovations can function. Future visions and expectations are used as resources to enrol other actors. These visions will be gradually refined through experiences from learning processes. Learning, network building and vision articulation are internal niche processes that have been analysed and described under the label of strategic niche management (Kemp *et al.*, 1998; Kemp *et al.*, 2001; Hoogma *et al.*, 2002).

The *macro-level* is formed by the *socio-technical landscape,* which refers to aspects of the wider exogenous environment, which affect socio-technical development (*e.g*. globalisation, environmental problems, cultural changes). The metaphor 'landscape' is used because of the literal connotation of 'hardness' and to include the material aspect of society, *e.g*. the material and spatial arrangements of cities, factories, highways, and electricity infrastructures. Landscapes form 'gradients' for action; they are beyond the direct influence of actors in the regime, and cannot be changed at will. The French historian Braudel (1958) coined the term '*la longue durée*' for such long-term structural backdrops of society. At this level, we can also refer to long-wave theories that highlight long-term changes in the entire economy. Economic growth and prices seem to follow long-waves of 50-60 year cycles (Freeman and Perez, 1988).

The relationship among the three concepts can be understood as a nested hierarchy, meaning that regimes are embedded within landscapes and niches within regimes (see Figure 4). The work in niches is often geared to the problems of existing regimes (hence the arrows in the figure). Actors support the niche hoping that novelties will eventually be used in the regime or even replace it. This is not easy, because the existing regime is entrenched in many ways (*e.g.* institutionally, organisationally, economically, culturally). Radical novelties may have a 'mismatch' with the existing regime (Freeman and Perez, 1988), and do not easily break through. Nevertheless, niches are crucial for system innovations, because they provide the seeds for change.

I will now describe how the three levels interact dynamically over time, and how this interaction results in transitions and system innovations. The dynamics will be described in four phases (see also Rotmans *et al.*, 2001).

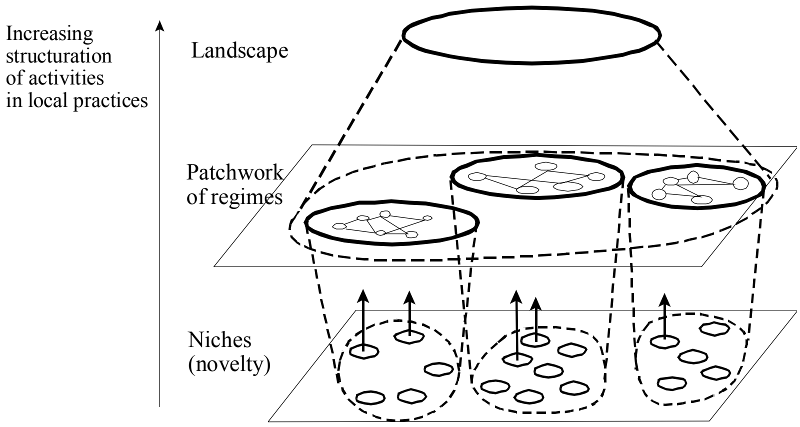

Figure 4. Multiple levels as a nested hierarchy (Geels, 2002a)

In the *first phase*, novelties emerge in niches in the context of problems in the existing landscape and regime. Both technical form and ideas about functionality are strongly shaped by the existing regime. There is not yet a dominant design, and there may be various technical forms competing with each other. Actors engage in experiments to work out the best design and find out what users want. The SCOT-approach highlights socio-cognitive processes and learning about meaning in social groups. Interpretative flexibility diminishes as consensus emerges about the dominant meaning of an artefact. LTS-approaches highlight product champions and system builders who weave heterogeneous elements into a working system. ANT-approaches emphasise how actors try to enrol each other to support innovations. They also show how new technologies, markets, user preferences and regulations shape each other as part of a translation and linkage process.

In the *second phase* the novelty is used in small market niches that provide resources for technical specialisation and exploration of new functionalities. Gradually, a dedicated community of engineers and producers emerges, directing their activities to the improvement of the new technology. They meet at conferences and discuss problem agendas, promising findings and search heuristics. Engineers gradually develop new rules, and the new technology develops a technical trajectory of its own. The new technology gradually improves as a result of learning processes. As users interact with the new technology and incorporate it into their practices, they build experience with it and gradually explore its new functionalities. This second phase results in a stabilisation of rules, *e.g.* a dominant design and articulation of user preferences.

The *third phase* is characterised by wide diffusion, breakthrough of new technology and competition with the established regime. There are two complementary explanations that can be used to explain the dynamics in this phase: external circumstances and internal 'drivers.'

External circumstances

The multi-level perspective highlights the point that breakthrough of novelties from the niche-level depends on niche-external circumstances at the regime and landscape level. Only if conditions in relating regimes and landscapes are simultaneously favourable will wide diffusion of the novelty occur. Such situations are called windows of opportunity. The following circumstances are important for windows of opportunity to arise: *(i)* internal technical problems in the regime, which cannot be met with the available technology; *(ii)* problems external to the system, negative externalities; *(iii)* stricter regulations, often in reaction to negative externalities; *(iv)* changing user preferences, which may lead to new markets with which new technologies may link; and *(v)* landscape changes that put pressure on the regime.

Internal 'drivers'

Besides such external circumstances at the regime level, there are also internal 'drivers' that stimulate diffusion of innovations. Disciplinary perspectives highlight different aspects.

– Economic: Improvements in cost/performance ratios stimulate wider diffusion. The performance of the new technology may be improved, as producers gain experience, *e.g.* learning by doing (Arrow, 1962). And there may be 'increasing returns to adoption' as highlighted by economic path dependence theorists[23];

– Socio-technical: In LTS- and ANT-approaches, the focus is on linkages in and around the emerging technology, and the activities of different actor-groups. The new configuration becomes more stable as more elements are linked together (*e.g*. technology, user practices, infrastructure, maintenance networks, regulations). The new system gains 'momentum' as more social groups have a vested interest in it;

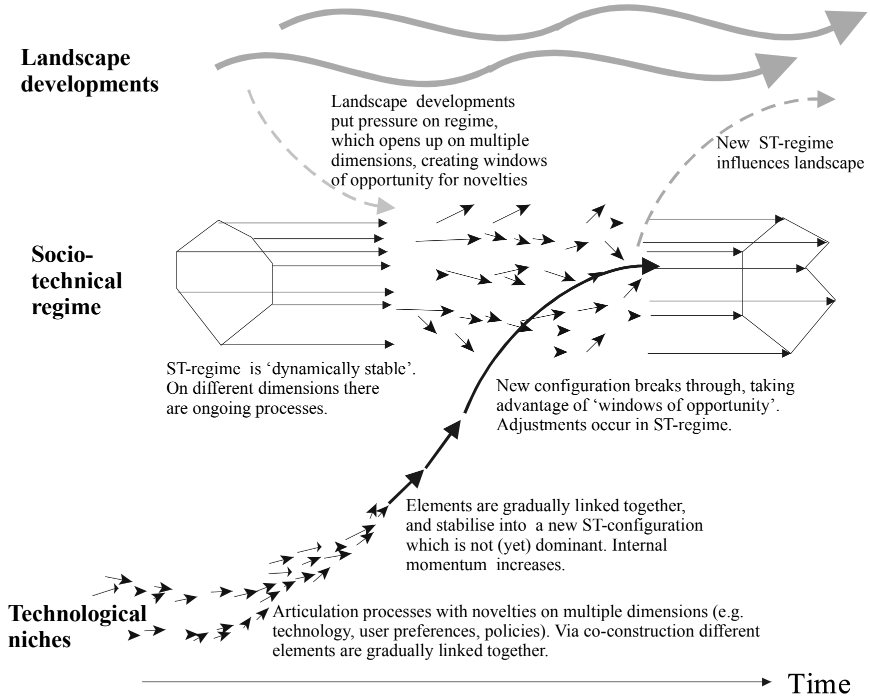

Figure 5. A dynamic multi-level perspective on system innovations (Geels, 2002b: 110)

[23] Arthur (1988: 591) identified five sources of increasing returns to adoption: *(i)* learning by using: the more a technology is used, the more is learned about it, the more it is improved; *(ii)* network externalities: the more a technology is used by other users, the larger the availability and variety of (related) products that come available and are adapted to the product use; *(iii)* scale economies in production, allowing the price per unit to go down; *(iv)* informational increasing returns: the more a technology is used, the more is known among users; *(v)* technological interrelatedness: the more a technology is used, the more complementary technologies are developed.

– Sociological: In the sociological literature (as in some business studies) the focus is on actors, organisations, groups and their perceptions, and (strategic) activities. All kinds of social mechanisms may accelerate or delay diffusion, *e.g*. hype and bandwagon effects, social struggles, effect of outsiders and strategic games, and the 'sailing ship effect.'[24]

In sum, the breakthrough of radical innovations depends both on internal drivers and niche-processes *and* on external developments in regimes and landscapes. The key insight of the multi-level perspective is that system innovations come about because developments at multiple levels link together and reinforce each other (see Figure 5). This means that system innovations are *not* caused by a change in a single factor or 'driver,' but are the result of the interplay of many processes and actors.

As the new innovation enters mainstream markets it begins a competitive relationship with the established regime. Economic considerations play an important role by instituting comparisons with regard to price and performance. From domestication and cultural studies, we know that the wide adoption of new technologies requires efforts by users to domesticate and integrate new technologies into their user practices. This may involve symbolic work, practical work and cognitive work by the users. Changes in user practices may lead to the articulation of new functionalities. Eventually, a new regime is formed, and a period of relative stability sets in.

In the fourth phase the new technology replaces the old regime, which is accompanied by changes in wider dimensions of the socio-technical regime. This often happens in a gradual fashion, because the creation of a new socio-technical regime takes time, *viz*. new infrastructures, new user practices, new policies. Furthermore, incumbents tend to stick to old technologies because of vested interests and sunk investments. They may also try to defend themselves, *e.g*. by improving the existing technology (sailing ship effect), political lobbying or evasion to other markets. The new regime may eventually also influence wider landscape developments. An example is the transition from sailing ships to steamships, which contributed to the expansion of worldwide trade, as freight tariffs went down. The importing of large quantities of cheap grain in Europe changed feeding patterns and raised standards of living and health, but it also threatened the livelihood of

[24] The sailing ship effect refers to the mechanism whereby actors associated with an incumbent technology greatly increase their innovative efforts when the established technology is challenged by a new technology. The term sailing ship effect was coined by Ward (1967), who referred to improvements in sailing ships when steamships challenged them in the 1860s and 1870s.

European farmers and led to the agricultural crisis of the 1890s. Steamships also contributed to the mass immigration to America in the late 19th and early 20th century. The transition to steamships thus contributed to many wider social and economic transformations (see Geels, 2002b).

The description of the four phases shows that the MLP is able to encompass insights from several disciplines. In Figure 6 I have schematically positioned the different disciplinary building blocks from Section 2 in the MLP, thus highlighting its integrative strength.

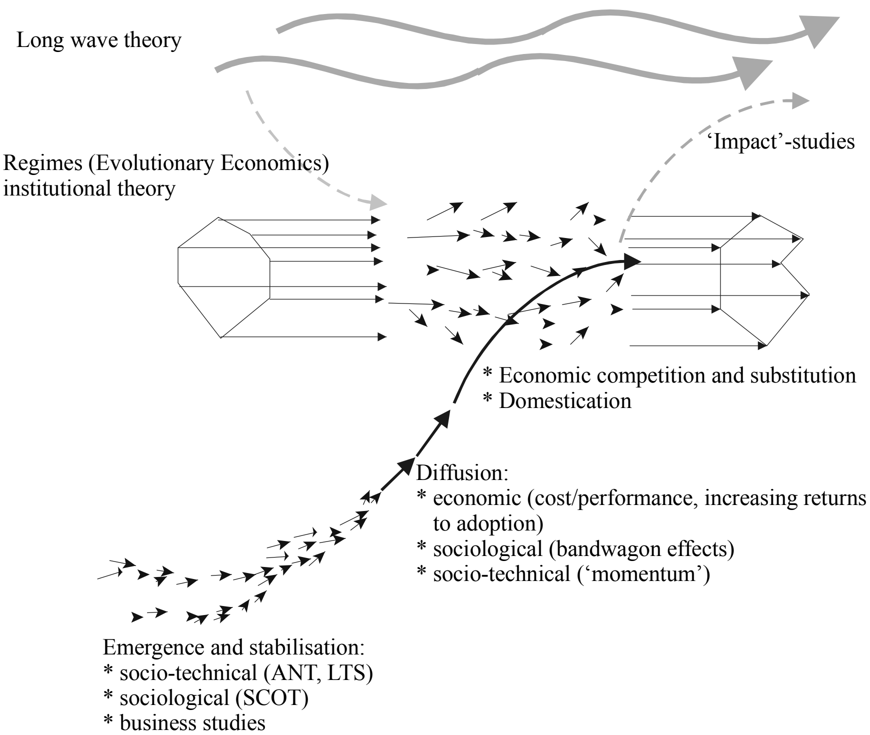

Figure 6. Positioning of different disciplines in the Multi-Level Perspective (Geels, 2004)

Empirical applications

The MLP has been empirically illustrated with historical case studies. Geels (2002b) studies the transition from propeller-piston engine aircraft to turbojets (1926-1975), the transition from sailing ships to steamships (1780-1914), and the transition in urban land transportation from horse-and-carriage to automobiles (1860-1930). Belz (2004) uses the MLP to study the ongoing transition in Switzerland (1970-2000) from industrialised agriculture to organic farming and integrated production. Van Driel and Schot (2001) use the perspective to study a transition in the transhipment of grain in the port of Rotterdam (1880-1910), where elevators replaced manual (un)loading of ships. Raven (2004) uses the perspective to study the niches of manure digestion and co-combustion in the electricity regime.

4. POLICY SUGGESTIONS

System innovations are complex, uncertain and involve multiple social groups. Hence policy makers puzzle over how they can influence system innovations. The state is not an all-powerful and all-knowing actor in this matter. Public authorities are only one social group amongst others. Like other groups, they have limited power, a limited cognitive perspective and limited resources to influence system dynamics. This recognition is represented in a shift in policy studies from a focus on government to governance (*e.g.* Kooiman, 1993; Kohler-Koch and Eising, 2000). Governance means that there is directionality and coordination at the systems level, but that it does not stem from one social group (*e.g.* policy makers). Directionality and coordination thus have an emergent character, arising from the interaction among groups. Public authorities may try to influence this, but cannot steer it at will. This means one has to be modest about the possibility for policy makers to steer system innovations. This is in line with the MLP, which highlights the importance of 'windows of opportunity' and the alignment of multiple developments. When existing socio-technical regimes are stable, policy makers cannot simply 'force' major changes, but they can stimulate variety at the niche level and try to modulate ongoing processes in the regime, aiming to make connections between the two levels. Different policy instruments can be used for these ends. The MLP does not so much propose *new* instruments, but suggests an overall framework for a better alignment of existing instruments. Let us first look at different instruments and then return to the MLP.

There is a wide range of policy instruments which stem from three different governance paradigms: *(i)* the traditional top-down model, with a central role for (national) government and hierarchical relations; *(ii)* a bottom-up market model, with a large degree of autonomy for local actors; *(iii)* a policy networks model, where actors are interdependent and have diverging values and beliefs. These three governance paradigms have different disciplinary backgrounds, focus on different aspects, encompass different notions about the relationship between the government and other actors, and propose different policy instruments (see Table 1). Formal rules and regulations are instruments typical to the command-and-control paradigm, while subsidies, taxes and (financial) incentives are common in the market model. Within the policy network paradigm the conspicuous leverages and instruments are learning processes, creation of shared visions, experiments and interactive policymaking.

Table 1. Different policy paradigms (based on De Bruijn et al., 1993: 22)

	Classic steering paradigm (top-down, command-and-control)	**Market model (bottom-up)**	**Policy networks (processes and networks)**
Level of analysis	Relationship between principal and agent	Relationship between principal and local actors	Network of actors
Perspective	Centralised, hierarchical organisation	Local actors	Interactions between actors
Characterisation of relationships	Hierarchical	Autonomous	Mutually dependent
Characterisation of interaction processes	Neutral implementation of formulated goals	Self organisation on the basis of autonomous decisions	Interaction processes in which information and resources are exchanged
Foundational scientific disciplines	Classic political science	Neo-classical economy	Sociology, innovation studies, neo-institutional political science
Governance instruments	Formal rules, regulations and laws	Financial incentives (subsidies, taxes)	Learning processes, network management through seminars and strategic conferences, experiments, vision building at scenario workshops, public debates

It is too simple to say that one paradigm is right and the others wrong. They emphasise different aspects of a (complex) reality. I argue that instruments from all three governance paradigms are needed to stimulate system innovations rather than making a choice for one particular instrument. I will use the MLP to formulate a general policy strategy to stimulate system innovations, and situate instruments in different phases and at different levels.

According to the MLP, a general transition policy strategy must have two characteristics. On the one hand, pressure on the existing regime should be increased. This can be done with financial instruments (*e.g.* carbon tax) and regulations (tradable emission rights, emission norms). On the other hand, radical innovations should be stimulated to emerge in niches. This requires more specific governance policies, *e.g.* subsidies for experimentation, network management to enrol the right actors in the niche, and the development of guiding visions and future expectations (*e.g.* Rotmans *et al.*, 2001; Hoogma *et al.*, 2002). This does not mean that governments 'pick the winners,' but that variety in innovation needs to be stimulated and guided.

This general strategy can be further refined. Different kinds of policies are needed in different phases and at different levels. In the first two phases, we need policies on the niche level to stimulate experimentation, learning, network building and vision building. Instruments from the network governance paradigm are relevant here. At the same time, regulative and financial instruments are needed to put pressure on the regime. There is no need to make this pressure very strong, unless the novelties have been improved sufficiently in niches (stabilised design, substantial improvements in price and performance). In the third and fourth phases, the system innovation gains momentum and goals become clearer. Policies are needed to push the new technology (*e.g.* regulations, adoption subsidies). Wide diffusion also requires adjustments in the socio-technical regime (*e.g.* new infrastructures, maintenance networks, regulations). Policies are needed for adjustment and structural change. At the same time, impacts of the new technology need to be monitored, and as more is learned about them, adjustment of policies is needed. Figure 7 schematically represents how instruments from different policy paradigms can be situated in different phases and levels.

The positioning of different policy instruments is ideal-typical and based on theory. The importance and precise mix of instruments may vary between domains and over time. Furthermore, countries may have different policy cultures, preferring different instruments, *e.g.* the US may prefer market-instruments, while the Netherlands chooses policy network instruments. However, scientific understanding has not progressed far enough to make robust conclusions about the 'best' mix of instruments in different domains, times and countries.

But we can take one further step. Because effective policies depend on windows of opportunity, it is helpful to identify some of those windows. Small interventions at the right moment can have large impacts later on. Here are some suggestions:

– Identify not only appropriate *initial* niches to experiment with new technologies, but also think in terms of *trajectories of niche-accumulation*. What could be the subsequent niches and application domains for the innovation?

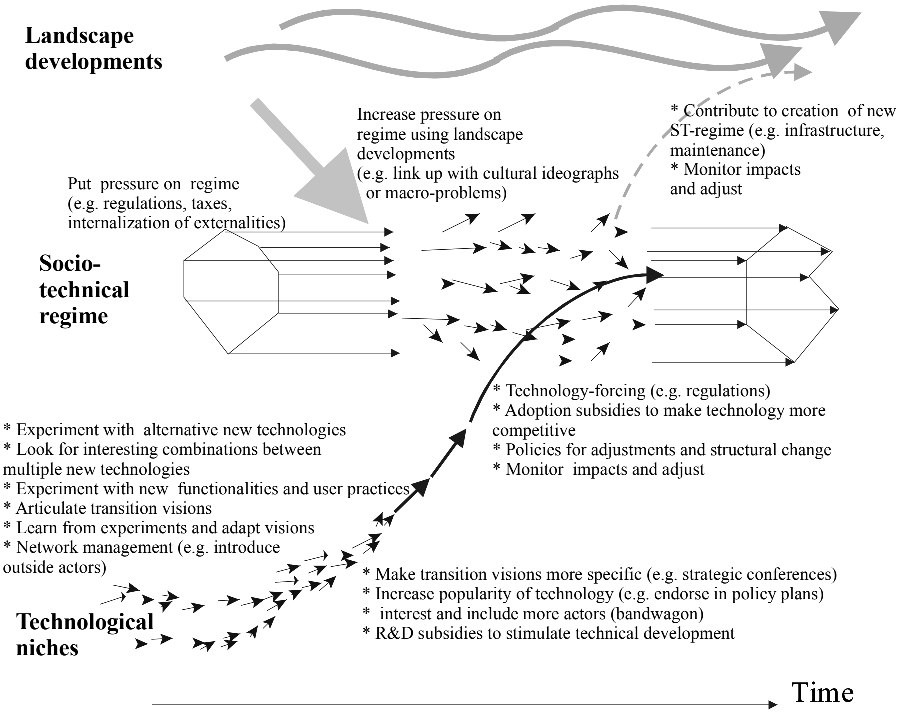

Figure 7. Different transition policies in different phases (Geels, 2002b: 363)

– Rather than focusing on single technologies as solutions, look for interesting combinations of *multiple* technologies. The transition to steamships occurred because three technical trajectories linked and reinforced each other: screw propulsion (instead of paddle wheels), iron hulls (instead of wood), and more efficient steam engines (compound engines) — which, in turn, depended on steel rather than iron;
– Search for possibilities of technical add-on and hybridisation as stepping-stones. Steam engines and paddle wheels were first used as auxiliary devices on sailing ships. Gas turbines were first used as auxiliary supercharging devices in piston-engine aircraft;
– Take advantage of market dynamics. Novelties may break out of niches by piggy-backing on the growth of particular market niches. If there is a market trend towards a second car in households, policy makers can oppose this dynamic to fight congestion. But they may also acknowledge the trend and try to stimulate the use of Battery-Electric Vehicles (BEV) in this market. This secondary market may then provide a stepping-stone for the diffusion of radical technology;
– Use new technologies to experiment with new functionalities and new user patterns. If innovations can be used in *new* markets, they need not

fight with incumbent technologies head-on. This means that established user patterns should not be taken for granted, but should be tested and questioned;
– Try to bring outsiders into the game. Incumbent actors may have too many vested interests to nurture a radical innovation. An outsider may speed up dynamics, and introduce new ways of doing and thinking.

5. TOPICS FOR FURTHER RESEARCH

The MLP provides an interesting overall perspective to understand system innovations. It has some strengths and weaknesses with regard to three scientific criteria: scope, empirical validity and simplicity (Ockham's razor). Strength of the MLP is its scope and generalizability. The perspective is broadly encompassing and able to combine contributions from sociological, economic and socio-technical theories. Another strength is that the perspective can accommodate complex empirical reality, although I have not been able to give detailed evidence of this point here (but see the references). A weakness is the use of metaphors and rather imprecise concepts (*e.g.* landscape, opening up, windows of opportunity). A problem for academics who like to make computer models is the low degree of simplicity. The perspective is fairly complex, requiring attention to dynamics at multiple levels.

There are also several gaps that need to be filled in with further research. One topic for further research is the elaboration of the multi-level perspective in terms of transition routes, patterns and mechanisms. A second topic is to look at the interaction among multiple niches. The MLP currently suggests that system innovation is about the breakthrough of one niche but there may be multiple niches accomplishing this. These niches can compete with each other, but they may also reinforce each other or co-exist with little interaction. This is an open and interesting topic.

A third topic is that closer cooperation should be sought with other disciplines, *e.g.* innovation studies and business studies. The sectoral systems of innovation approach, for instance, may have interesting insights to offer (Breschi and Malerba, 1997; Malerba, 2002), and from business studies we may learn more about the role of firms in different stages of system innovations, *e.g.* the relationship between incumbent firms and outsiders.

A fourth suggestion is to widen the empirical basis. More case studies should be done of system innovations, chosen from different domains so that the importance of different variables can be analysed (*e.g.* with or without infrastructure; private versus public sector; sectors with few large firms versus many small firms; internal problems versus negative externalities). When historical case studies are done, attention should be paid to the issue of the applicability of received insights to present-day contexts.

A fifth topic is the definition of boundaries. This is relevant for all research dealing with systems. More work should be done on this issue, because it is important to have the unit of analysis clear. On the other hand, perhaps we should not over-emphasise this issue. Particularly with regard to social networks, it is simply not possible to define boundaries once and for all. Social groups and the networks among them are the outcome of historical differentiation processes. The network of social groups, and associated socio-technical systems, develops over time. Relationships between social groups shift and new groups emerge. In the electricity sector, for instance, liberalisation has given electricity distribution companies a more prominent role, and electricity traders in spot markets have emerged as an entirely new group. Another point is that the specific network of social groups shows great differences between sectors. The social networks in transport systems look and function differently than in electricity systems. Questions about boundary definition always occur in systems and networks, but this is more an empirical issue than a theoretical one.

A sixth topic is the relationship between different policy paradigms. More should be done to determine how different instruments should be used in different phases. Historical case studies may act as an interesting mirror, but more attention also needs to be paid to differences between domains, times and countries. More international comparative work is required as system transformations become an increasing concern globally.

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Chapter 10

MANAGING TRANSITIONS FOR SUSTAINABLE DEVELOPMENT

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Abstract: The challenge of sustainable development presents our society with the need for long-term structural changes or transitions in sectors such as energy-supply, mobility, agriculture and health-care. Based on a multi-phase and multi-level framework for transitions, we ask whether managing transitions is possible, and then outline an operational method for transition management.

Key words: transitions, transition management, sustainable development

1. INTRODUCTION

Our society is increasingly facing persistent problems that cannot be solved by current policies based on traditional approaches alone. Too often, these policies lead to sub-optimal solutions, generating even more persistent and complex problems in the long term. Examples of these problems can be found in many European sectors: the agricultural sector, with its many symptoms of unsustainability, visible in diseases like Bovine Spongiform Encephalopathy (BSE)[25] and 'Foot & Mouth'; the water sector, with symptoms like floods, droughts and water quality problems; the energy sector, with its one-sided and environmentally-detrimental energy supply system; the transport system, with its concomitant air pollution and

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[25] Bovine Spongiform Encephalopathy (BSE) or mad cow disease.

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congestion; and the health care system, with its exorbitant costs and waiting lists in the face of an ageing population. These persistent problems are complex, unstructured, involve many stakeholders, are surrounded by fundamental uncertainties, and are deeply rooted in our societal structures and institutions (Dirven *et al.*, 2002). Their resolution demands a revision of both development processes and the institutions that have been built to handle them.

In order to resolve persistent societal problems, structural transformations or *transitions* are necessary. In general terms, a transition can be portrayed as a long-term process of change during which a society or a subsystem of society fundamentally changes (Rotmans *et al.*, 2000, Rotmans *et al.*, 2001). Transitions require system innovations: organisation exceeding, qualitative innovations, which are realised by a variety of participants within the system and which fundamentally change both the structure of the system and the relation among the participants. It is within these systemic innovations that innovations at the individual level occur, in terms of product, process and project innovations (Weaver *et al*, 2000). An example is a possible future energy transition to biomass, which will involve system innovations in transport (biofuels), electricity generation (co-combustion, gasification of biomass), agriculture (biocrops), as well as in policy (integral biomass policy regarding energy, biodiversity, space use, agriculture and transport) and culture (surmounting barriers among the public against alternative energy carriers).

The relation between transitions and system innovations on the one hand, and sustainable development on the other hand, is ambiguous (Kemp and Rotmans, 2001). Many transitions and system innovations that happened in the past were not set in motion based on a preconceived goal, and did not lead to a more sustainable society. On the contrary, the detrimental environmental impact of technological innovations often outweighed the positive impacts of an efficiency increase. The fact that we currently face the need to innovate and structurally change a number of societal systems is a tremendous challenge: to initiate transitions and system innovations from the preconceived goal of sustainable development. Because sustainable development is intrinsically a normative, ambiguous and subjective notion, a practical implementation of sustainable development has to incorporate the inherent conflicts between the values, ambitions and goals of a multitude of stakeholders.

2. SCIENTIFIC PERSPECTIVE

Within the Dutch Knowledge network on System Innovations and Transitions (KSI)[26] an inter- and transdisciplinary science perspective has been developed, represented in an overall research programme on transitions and system innovations (Rotmans *et al.*, 2003). This new science perspective is based on a set of shared concepts and aims to develop a deeper and broader knowledge base for transitions and system innovations. As Berkhout *et al.* (2003) argue, we need a thicker context-enriched understanding of transitions.

> **A transition**
>
> … is the shift from an initial dynamic equilibrium to a new dynamic equilibrium
>
> … is characterised by fast and slow developments as a result of interacting processes
>
> … involves innovation in an important part of a societal subsystem
>
> (Kemp and Rotmans, 2001)

The first shared concept is that of transition itself. From an integrated systems perspective, we define the concept of a transition as a shift in a system from one dynamic equilibrium to another equilibrium. The process of change in transitions is highly non-linear: slow change is followed by rapid change when things reinforce each other, which again is followed by slow change in the new equilibrium.[27] The underlying mechanism is that of co-evolution, because different subsystems co-evolve with each other, leading to irreversible patterns of change. There are multiple shapes a transition can take, but the common shape is that of a sigmoid curve such as that of a logistic at the most aggregated level. For example, population size followed an S-curve in the demographic transition. A transition can be accelerated by one-time events, such as a war or large accident (*e.g.* Chernobyl) or a crisis (such as the oil crisis), but cannot be caused by such events. That is due to the co-evolution of a set of slow changes that determine the undercurrent for a fundamental change.

[26] The KSI-network comprises about 70 researchers with specific knowledge and expertise of transitions and system innovations. These are not people with domain-specific knowledge, such as energy, agriculture, transport, or space utilisation. Their knowledge is more in the sense of transition process architecture, system knowledge of transition, competence, learning processes in transitions, competence development in transitions, and instruments for initiating, guiding, monitoring, and evaluating transitions.

[27] This pattern of change seems to coincide with the four phases in the development of ecological systems that Gunderson and Holling discern (2001).

Superimposed on this undercurrent are events such as calamities, which may accelerate the transformation process.

Although each transition is unique in terms of content and context, we may distinguish between two types of transitions (Kemp and Rotmans, 2004):

– Evolutionary transitions, in which the outcome is not planned in a significant way; and
– Goal-oriented (teleological) transitions, in which (diffuse) goals or visions of the end state are guiding public actors and orienting the strategic decisions of private actors.

With this preliminary typology we do not pretend to capture all forms of transition, but try to indicate that transitions differ by nature, scope and driving forces. An example of an evolutionary transition is the transition from sailing ships to steam boats (Geels, 2002), while an example of a goal-oriented transition could be the transition in water management in the Netherlands, which we will elaborate on in Section 3 (Van der Brugge *et al.*, 2004).

A second, shared KSI concept concerns a transition framework. This framework can serve as a bridge between the different disciplines studying partial aspects of transitions and system innovations. We use a preliminary framework, which consists of two transition concepts: the multi-phase and multi-level concepts (Rotmans *et al.*, 2000; Geels and Kemp, 2000). The multi-phase concept indicates that transition paths are highly non-linear with different phases, shifting from one dynamic equilibrium to another. In general, we presuppose that a transition takes place through the following stages (Figure 1):

– A *pre-development phase* where there is very little visible change at the systems level but a great deal of experimentation at the individual level;
– A *take-off phase* where the process of change starts to build up and the state of the system begins to shift because of different reinforcing innovations or surprises;
– An *acceleration phase* in which structural changes occur in a visible way through an accumulation and implementation of socio-cultural, economic, ecological and institutional changes; and

A *stabilisation phase* where the speed of societal change decreases and a new dynamic equilibrium is reached.

The multi-level concept describes a transition in terms of different scale dynamics, which are interlinked (Geels and Kemp, 2000; Rip and Kemp, 1998). The multi-level concept makes a distinction between niches, regimes and the socio-technical landscape at three interacting scale levels: the micro-, meso- and macro-level. At the macro-level the societal landscape is determined by slow changes in society. Operating at the meso-level are the social norms, interests, rules and belief systems that underlie companies', organisations' and institutions' strategies and political institutions' policies. Acting on the micro-level (niche-level) are individual actors, technologies and local practices. At this level, variations to and deviations from the *status quo* can occur as a result of new ideas and new initiatives, such as new techniques, alternative technologies and different social practices. This concept is extensively discussed in chapter 9 by Geels in this volume.

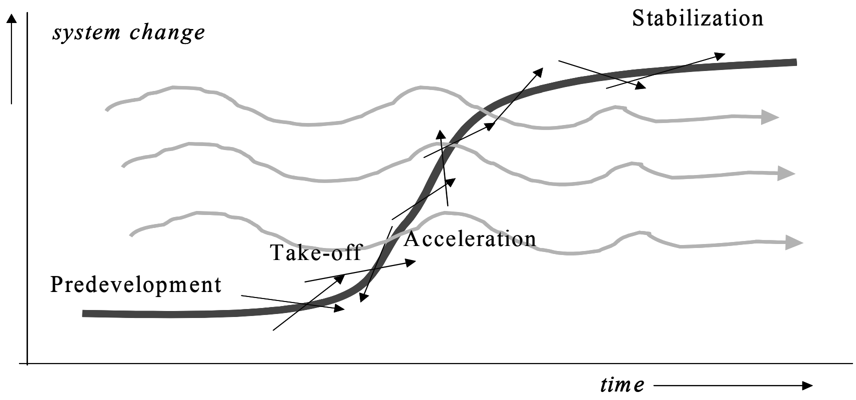

Figure 1. Different stages of a transition at different system levels (Rotmans et al., 2000)

The third shared concept is that of transition management (to which we will return in Section 4), which is rooted in fields such as multi-level governance and adaptive management (Rotmans *et al.*, 2000). This concept indicates that, although transitions cannot be managed in terms of command and control, they can be managed in terms of influencing and adjusting: a more subtle, evolutionary way of steering. In other words, the direction and pace of transitions can be influenced, even if not controlled directly. Transition management therefore aims to better organise and coordinate transition processes at a societal level, and tries to steer them in a sustainable direction.

Based on the above-described shared research concepts, the following objectives have been derived, as specified by KSI (Rotmans *et al.*, 2003):

- To further develop the theoretical concepts for describing and explaining transitions to sustainability, and empirically testing these theoretical axioms;
- To develop a new governance concept that reflects the principles of transition management, and to test the principles underlying this new paradigm by applying them in practical transition experiments; and

– To further develop existing practical tools and instruments, and develop new tools and instruments to adequately initiate, stimulate, support, monitor, effectuate and evaluate transitions and system innovations.

The complex systems approach is central to this research program (*e.g.* Von Bertalanffy *et al.*,1951; Holland, 1995; Midgley, 2003). It should not be regarded as a straightjacket, however, but as an over-arching way of thinking within which other research approaches can fit. The rationale for taking the complex systems approach as an umbrella for studying current and future transitions and system innovations is threefold: *(i)* the transition domains of our research foci could be considered as complex systems themselves; *(ii)* the close and recursive relation between transitions and system innovations, which makes the complex systems approach an obvious choice; and *(iii)* as a unifying principle, the complex systems approach offers a framework for synthesizing different knowledge strands which is necessary for addressing transitions and system innovations.

3. THE WATER TRANSITION

A good example of the dynamics of transitions, as well as of how the multi-phase and multi-level approach can serve to analyse transitions, is the transition that has occurred in Dutch water management over the last decades. This example is interesting, particularly because it resembles not so much an example of a shift in technological regime, but rather a shift in management style and institutional regime.

For an extensive description of this transition case we refer to Van der Brugge *et al.* (2004). Since the 1970s, a shift from a technocratic water management style to the current practice of integrative and participatory water management took place. The construction of the famous Delta Works in retrospect seems to have been an important turning point in the shift from the old to the new water perspective. This prestigious water defence project in the Dutch province of Zeeland had profound consequences for the surrounding nature and its ecological functions. The planning process for the construction of the Eastern Scheldt storm surge barrier (one of the Delta Works) started in the mid sixties. It was a time of growing attention towards environmental issues both at the local and at the global level; the vulnerability of nature due to human interventions was becoming clearer (changing the macro-landscape).

Furthermore, the direct ecological consequences of the Delta Works were so profound that ecosystems were destroyed or changed. The protests against the Eastern Scheldt storm barrier slowly found their way to national debates, gradually increasing the pressure on the water management regime. This was reflected in reports such as '*Dealing With Water*' (RIZA, 1985), which articulated for the first time some of the problems concerned with the then current water-management style. In that same period, the first building blocks for integrated water management came from niches outside the water regime. In 1987, six people from the Dutch ministry of Agriculture, Nature and Fishery (LNV) and Rijkswaterstaat (the leading Dutch water management institution) won the national Eo Wijers 'Netherlands — Riverland' contest regarding the future of Dutch water management, with a plan called 'Plan Ooievaar' From an environmental point of view, the plan contained original and innovative ideas with regard to future water management.

At the end of the 'eighties, an obvious change in water management was underway. The third national memorandum on water management (Rijkswaterstaat, 1989) built upon the vision presented in 'Dealing With Water' and 'Ooievaar' (Bruin *et al.*, 1987). In the memorandum, the water regime actors expressed their interest in the integrated water management concept. However, the resistance from regime actors against the approach was immense. The district water boards, for instance, promptly took the position that this strategy could not be realised and was unfeasible. These boards were traditionally split up into small-scale quantity water board units and large-scale quality water board units. Their opposition was not surprising, however, because as a consequence of implementing the integrated water management concept presented in the memorandum, the first steps were taken to reorganise and reorient these district water boards.

The emergence of the new perspective coincided with a gradual destruction of the old regime, which characterised the pre-development phase. During the 1980s and 1990s, Dutch policy promoted the decentralisation of government while stimulating privatisation and liberalisation. In general, the decentralisation trend in The Netherlands also had its effect on water management and its institutions. More and more work had to be done by parties other than Rijkswaterstaat, and regional directories were becoming more independent from the central government. On the one hand, this resulted in a decreasing number of staff within Rijkswaterstaat. On the other hand, the focus on ecological consequences required other competencies and new professions in the hierarchical regime of water engineers. The slow depletion of the old regime paved the way for water management to become a more multi-disciplinary and less hierarchically managed regime.

Large-scale calamities during the 1990s (*e.g.* river floods and near-disastrous high river discharges) created momentum for the further implementation of the new water strategy. The floods brought water management back on the political agenda. But there still is a considerable gap between the conceptual and theoretical notions behind the new water management, and actual practice. Water management should be based on principles of uncertainty, anticipation and participation, and the whole of water management should be more adaptive to rapidly changing external forces.

In sum, from a multi-phase perspective, the pre-development phase of the water transition had already started in the 1960s with the construction of the Eastern Scheldt storm surge barrier. The shift from the pre-development phase to the take-off phase took place around 1995, after the second major flood. By then, the new perspective had become strong and consistent enough, but this convergence had particular consequences for water management. Now, in 2004, the integrated vision on water management, nature development and spatial planning, is broadly supported and disseminated by many water managers, spatial planners and nature preservers. Implementation of this new water vision is now taking shape in the water regime at the meso level, indicating that the transition is somewhere close to the acceleration phase (Van der Brugge *et al.*, 2004).

Analysing this transition from the multi-level perspective shows that the initiatives and developments at the micro-level (ecological concerns, spatial planning issues, individual innovators) were gelling with changes at the landscape level (in terms of growing awareness of the ecology and climate change) in such a way that the predominantly technocratic water management regime could be influenced by innovators and innovations. Currently, these different developments are modulating and reinforcing each other, leading to structural changes in institutions as well as physical infrastructures. In our analysis, this means that the transition is at the take-off stage, nearing the acceleration stage. But while this change is obviously taking place, the transition could easily get ‘locked-in’ because of the problems that arise while implementing large-scale transition plans. The most important aspect in this regard is to co-ordinate experiments in such a manner that they contribute to system innovation towards a more sustainable regime. Various experiments have been set out in the field of integrated water management, but without overall coordination of these experiments or a unifying transition direction. What is now needed seems to be an overall approach that takes into account the mentioned complexities and uncertainties but at the same time allows for experiment and innovation. The question, of course, is whether such a process can indeed be managed or steered in a desired direction.

4. POSSIBILITIES FOR MANAGING TRANSITIONS

What are the possibilities for managing transitions? Can transitions be managed? The simple answer to these questions is that transitions cannot be managed in the traditional sense. The reason is that transitions are the result of the interplay of many unlike processes, several of which are beyond the scope of management, such as cultural change, which can be considered an autonomous process. What one *can* do, however, is influence the direction and speed of a transition through various types of steering and coordination. Thus, transitions defy control but they can be influenced. The management of transitions can be done through the (direct and indirect) use of three co-ordination mechanisms: markets, plans and institutions.[28] Transition management uses markets by relying on price mechanisms and decentralised decision-making for making product and service choices. It makes use of planning in the form of transition goals, policy strategies and objectives that centrally coordinate economic activities. Institutional coordination, the third type of co-ordination, consists of new models for policy, the development of transition arenas, agendas and goals, the fostering of new networks, and a focus on learning processes. In transition management, transition arenas play a crucial role. Transition arenas are networks of innovators and visionaries that develop long-term visions and images that, in turn, are the basis for the development of transition-agendas and transition-experiments, involving growing numbers of actors.

In this section we offer a conceptual as well as a practical model for managing transitions to sustainability. The conceptual model has been developed and used for the 4th National Environmental Policy plan of the Netherlands (NMP-4). Transition management consists of a deliberate attempt to stimulate a transition towards a more sustainable future. There are different ways of trying to achieve a transition. One can opt for the use of economic incentives, rely on a planning and implementation approach, or use a combination in the form of market-based planning derived from institutional strategies and sustainability visions.

The basic steering philosophy underlying transition management is that of *anticipation and adaptation,* starting from a macro-vision on sustainability, building upon bottom-up (micro) initiatives, while in the meantime influencing the meso-regime. Goals are chosen (often implicitly through debates and opinions) by society, and the systems designed to fulfil these goals are accordingly created through a bottom-up approach using

[28] We use the terms institutions to refer to organisations and regulation as well as to 'soft' institutions such as behaviour and routines.

adaptive policies. The policies designed to further the goals are not set into stone but are constantly assessed and periodically adjusted in development rounds (Teisman, 2000). Existing and possible policy actions are evaluated against two criteria: first, the immediate contribution to policy goals (for example, in terms of kilotons of CO_2 reduction and reduced vulnerability through climate change adaptation measures); second, the contribution of the policies to the overall transition process. A schematic view of transition management is given in figure 2.

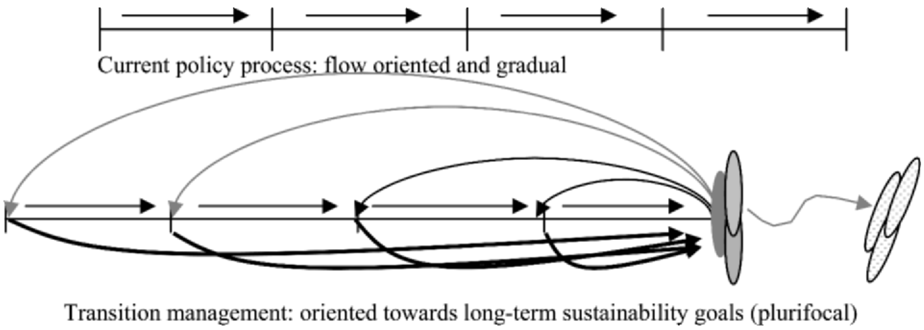

Figure 2. Current policy process versus transition management process

Transition management is based on a two-pronged strategy. It is oriented towards both system improvement (improvement of an existing trajectory) and system innovation (representing a new trajectory of development or transformation). The role of government varies per transition phase. For example, in the predevelopment stages there is a need for social experimentation and creating support for a transition programme, the details of which should evolve with experience. In the acceleration phase there is a special need for controlling the side effects of large-scale applications of new technologies.

Transition management breaks with the old planning-and-implementation model aimed at achieving particular outcomes. It is based on a different, more process-oriented and goal-seeking philosophy which helps to deal with complexity and uncertainty in a constructive way. As such, transition management also breaks with the famous Dutch consensus-based or polder-model by opting for consensus on long-term sustainability goals, while at the same time allowing for diversity and informed dissent in the short term.

Key elements of transition management are:

– Systems-thinking in terms of more than one domain (multi-domain) and different actors (multi-actor) at different scale levels (multi-level); analysing how developments in one domain or level gel with developments in other domains or levels; trying to change the strategic orientation of regime actors;

- Long-term thinking (at least 25 years) as a framework for shaping short term policy;
- Back- and fore-casting: the setting of short-term and longer-term goals based on long-term sustainability visions, scenario-studies, trend-analyses and short-term possibilities;
- A focus on learning and the use of a special learning philosophy of learning-by-doing and doing-by-learning;
- An orientation towards system innovation and experimentation;
- Learning about a variety of options (which requires a wide playing field); and
- Participation from and interaction between stakeholders.

The transition management cycle

Transition management conceptually can be described as a cyclical and iterative process. To make the conceptual model of transition management outlined above operational, transition management could be organised in so-called development rounds. In this section we will present a model to make transition management operational, which is being tested at various (governmental) levels.[29] One round consists of four main activities: establishing and further developing a transition arena for a specific transition theme; the development of a long-term vision for sustainable development and a common transition agenda; the initiation and execution of transition-experiments; and the monitoring and evaluation of the transition process. Those four activities are (cyclically) represented in Figure 3. Based on the experiences now available, one transition cycle is estimated to take about two to five years, depending on the practical context within which one has to operate.

The establishment, organisation and development of a transition-arena

The establishment and organisation of a transition-arena forms the basis of the transition management process. The selection of participants for the transition arena is of vital importance; they need to reflect the complexity of the transition at hand. Participants need to have some basic competencies at their disposal: they need to be visionaries, forerunners, able to look beyond

[29] In the Netherlands, the model has been adopted by five different ministries, who are trying to implement it, see for example: www.energietransitie.nl.

their own domain or working area, and be open-minded. They must function quite autonomously within their organisation but also have the ability to convey the developed vision(s) and develop it (them) within their organisation(s). Apart from this, they need to be willing to invest a substantial amount of time and energy in playing an active role in the transition arena process. It is important to specify explicitly the criteria with which the participants of the transition arena are selected, and to document these criteria.

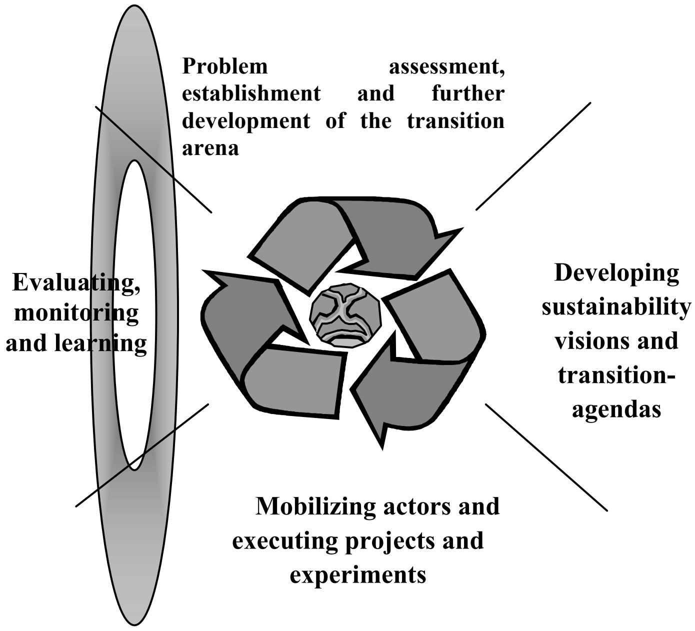

Figure 3. Activity clusters in transition management

Another important element is the facilitation of the transition arena. Not only facilitation in process terms but also in terms of substance. A continuous process of feeding the participants in the arena with background information and detailed knowledge on a particular topic is necessary to enable a process of co-production of knowledge among the participants. This is of vital importance because arena experiences show that in most cases arena participants have insufficient time, lack specific knowledge or do not have enough perspective with which to deepen their understanding of the often complex problems that arise. Therefore, they must be fed substantive knowledge, just as the knowledge developers must in turn be fed (tacit) knowledge from the arena participants. This substantive support concerns issues such as framing the transition issue in time and space and in relation with other issues in other relevant fields, the development of a shared problem perception (what is the deeper problem we perceive?) and the sense of urgency that may or may not be shared.

There is an important role here for the transition manager, who brings together the various parties, is responsible for the overall communication in the transition arena, acts as intermediary in discordant situations, and has an overview of all the activities in the arena. The transition manager should also ensure a balanced representation of participants from business, governments, non-governmental organisations, knowledge institutions, and end-users/consumers. After some time, arena participants may be replaced by new participants with other competencies and practical orientations. The transition manager guards this substitution process carefully in order not to disturb the balance in the arena.

The development of sustainability visions and a transition agenda

Organising an envisioning process for sustainable development is a difficult task. It requires questioning one's own paradigm and leaving aside the concomitant everyday noise. It also requires insight and imagination to look ahead one or two generations. Last, but not least, it requires reaching agreement among often diverging opinions on what sustainability means for a specific transition theme. Many sustainability visions are still imposed by the government upon other parties in a top-down matter, or originate from a selected group of experts who are far from representative of the broad social setting.

The long-term visions of sustainability can function as a guide for formulating programmes and policies and setting short-term and long-term objectives. These visions must be as appealing and imaginative as to be supported by a broad range of actors. Inspiring final visions are useful for mobilising social actors, although they should also be realistic about innovation levels within the functional subsystem in question.

The inspiring, imaginative and innovative transition visions are represented by transition images. Rather than considering transition images as optimal societal blueprints, we consider transition images as integral target images that evolve over time and depend on new insights and learning effects. The transition images embrace transition goals, which are qualitative rather than quantitative, multi-dimensional, and should not be defined in a narrowly technological sense, but should represent the three dimensions of sustainability: economic, ecological and socio-cultural. Ideally, the images should be democratically chosen and based on integrated risk analysis, but this does not imply a consensus on these goals since a number of (even contradicting) images and goals can be chosen. This way, multiple transition visions, represented by multiple transition images, are developed, creating a basket of images as represented in Figure 4. The fact that sustainability is an essentially contested notion is thus addressed by allowing for diversity in the short term while trying to achieve consensus on long-term ambitions. In real life, a number of possible interpretations, expectations and visions related to the future will be present, making it impossible to reach a short-term consensus.

Various transition pathways lead to a particular transition image, and from various transition images a particular transition pathway may be derived. The transition images can be adjusted as a result of what has been learned by the players in the various transition experiments. The participatory transition process is thus a goal-seeking process where the transition visions and images, as well as the underlying goals, change over time. This differs from so-called 'blueprint' thinking, which operates from a fixed notion of final goals and corresponding visions.

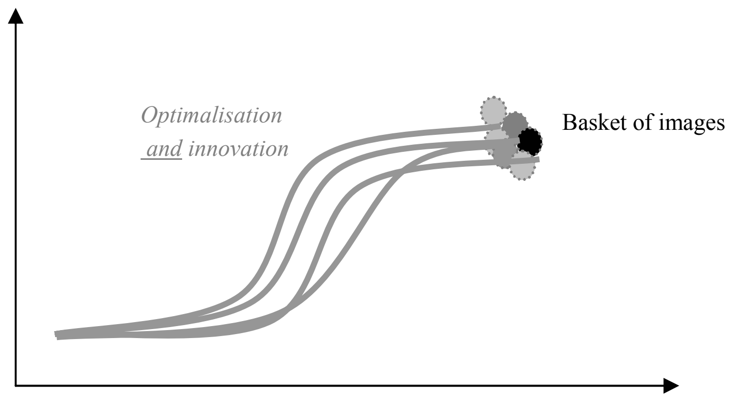

Figure 4. Transition process as a goal-seeking process

Based on a process of variation and selection, new visions and images emerge, others die out, and existing ones will be adjusted. Only during the course of the transition process will the most innovative, promising and feasible transition visions and images be chosen. This evolutionary goal-seeking process means a radical break with current practice in environmental policy, where quantitative standards are set on the basis of studies of social risk, and adjusted for political expediency. Risk-based target setting is doomed to fail when many issues are at stake and when the associated risks cannot easily be expressed in fixed, purely quantitative objectives.

Figure 3 shows the similarities and differences between current policy-making and transition management. In each case, interim objectives are used. However, in transition management these are derived from the long-term objectives (through 'back-casting'), and contain qualitative as well as semi-quantitative goals and measures. In other words, the interim transition objectives contain *content* objectives (which, at the start, can look like the current policy objectives, but later will look increasingly different), *process* objectives (speed and quality of the transition process) and *learning* objectives (what has been learned from the experiments, what is blocking progress, identification of things that we want to know).

Based on the common problem perception and the shared sustainability vision(s), a joint transition agenda can be designed. This is important because all arena participants take their own agenda into the transition arena, whereas a joint transition agenda contains common problem perceptions, goals, action points, projects and instruments. The means for effectively executing the proposed plans are important in order to resolve the problems on the transition agenda as adequately as possible. A transition agenda is actually a joint action programme for initiating or furthering transitions. It is important to set down which party is responsible for which type of activity, project or instrument to be developed or applied. The monitoring of this joint action programme is important in order to guarantee that the transition agenda is complied with as closely as possible. Instruments are used here in the broad sense: from tax measures to public-private arrangements, but also new instruments, for example systemic instruments (Smits and Kuhlmann, 2002). The transition agenda forms the compass, which the transition arena participants can follow during their transition journey.

An insufficiently robust and ill-supported transition agenda creates a serious barrier for transition management. If the transition manager under-invests in the quality of the transition agenda, many problems remain below the surface, which will arise later in the transition process. An adequate transition agenda, however, can form a binding element in the transition process. The transition agenda requires a balance between structure and flexibility. Structure is needed to position the scale levels in which the issue in question plays, and to frame the issue in terms of themes and sub themes. The coherence between the various sub themes and scale levels is a separate and important point on the transition agenda. Structuring the transition agenda is time-consuming but pays off in the form of increased quality of the transition management process (Dirven, Rotmans and Verkaik, 2002). On the other hand, flexibility is needed because the transition agenda is dynamic and changes over time. In the longer term, themes, goals, means and instruments change, and so the transition-agenda evolves. Practically, the transition agenda forms the long-term context for short-term policy, within which the current policy fits. If this does not match, the short-term agenda needs to be adjusted. This is an iterative, cyclical and learning process.

The initiation and execution of transition-experiments

From the transition visions and images, transition-experiments are derived. The transition-experiments are supposed to contribute to the sustainability goals at the system level and should fit within the transition pathways. It is important to formulate sound criteria for the selection of experiments and to make the experiments mutually coherent. The crucial point is to measure to what extent the experiments and projects contribute to the overall system sustainability goals, and to measure in what way a particular experiment reinforces another experiment. Are there specific niches for experiments that can be identified? What is the attitude of the current regime towards these niche experiments? The aim is to create a portfolio of transition experiments that reinforce each other and contribute to the sustainability objectives in significant and measurable ways.

Preferably, these experiments should link up with ongoing innovation projects and experiments in a way such that they complement each other. Often, many experiments exist, but are not set up and executed in a systematic manner, resulting in a lack of cohesion. Because transition-experiments are often costly and time-consuming, the existing infrastructure for innovation experiments should be used as much as possible. A lack of cohesion puts constraints on the feasibility and running time of experiments. The execution of experiments should be done through the existing networks of arena participants to ensure the direct involvement of these forerunners within participating organisations.

Transition processes are beset with structural uncertainties of different kinds. It is, therefore, important to keep a number of options open and to explore the nature of these uncertainties in the transition-experiments in order to determine which uncertainties are structural and which ones can be reduced. Uncertainties can be the result of a lack of knowledge and may thus be reduced, but they can also be caused by the variability of the system, and so are structural and irreducible by nature. In the transition management cycle these uncertainties need to be explored and mapped in a systematic manner. Through learning with transition-experiences the estimation of these uncertainties changes in the course of the transition process. This, in turn, may lead to adjustment of the transition visions, images and goals. In this search and learning process, scenarios play an important role, in particular explorative scenarios, which attempt to explore future possibilities without very many decision-making constraints (Van Notten *et al.*, 2003).

Monitoring and evaluating the transition process

Continuous monitoring is a vital part of the search and learning process of transitions. We distinguish between two different processes to be monitored: the monitoring of the transition processes itself, and the monitoring of transition management. Monitoring the transition process itself has to take place at different levels in terms of monitoring the slowly changing macro-developments, the sharply fluctuating niche developments, as well as the individual and collective actors at the regime level. This provides the ‘enriched context’ for transition management. The monitoring of transition management requires a different form of monitoring. First, the actors within the transition arena must be monitored with regard to their behaviour, networking activities, alliance forming and responsibilities, and also as to their activities, projects and instruments. Next, the transition agenda must be monitored with regards to the actions, goals, projects and instruments that have been agreed upon. Finally, the transition process itself must be monitored with regards to the rate of progress, the barriers and points to be improved, *etc*.

Learning-by-doing and doing-by-learning is the essence of transition management. Learning-by-doing concerns the development of theoretical knowledge from practice, whereas doing-by-learning is the development of practical knowledge from theory. Monitoring these learning processes, however, is easier said than done. Hardly any experience has been had with monitoring and documenting these kinds of learning processes. The phenomenon of ‘(social) learning’ is, for many, still an abstract notion that cannot be easily translated into components for monitoring. It is, therefore, important to formulate explicit learning goals for transition experiments, which can be monitored.

The evaluation of the above learning processes is in itself a learning process, and may lead to adjustment of the developed transition vision(s), transition agenda, and the transition management process within the transition arena. The set of interim objectives are evaluated to see whether they have been achieved; if this is not the case, they are analysed to see why not. Have there been any unexpected social developments or external factors that were not taken into account? Have the actors involved not complied with the agreements that were made? Once these questions have been answered, a new transition management cycle starts which takes another few years. In the second round of this innovation network the proliferation of the acquired knowledge and insights is central. This requires a specific strategy for initiating a broad learning process.

Because these transition management cycles take several years within a long-term context of 25-50 years, the creation and maintenance of public support is a continuous concern. When quick results do not materialise and setbacks are encountered, it is important to keep the transition process going and to avoid a backlash. One way to achieve this is through participatory decision-making. Societal support can also be created in a bottom-up manner, by bringing in experiences with technologies in areas in which there is local support. The experience may remove broader fears and give proponents a weapon. With time, solutions may be found for the problems that limit wider application.

5. CONCLUSIONS

In this chapter we have outlined the models of transitions and transition management for achieving a more sustainable society. We have argued that transitions are necessary to achieve more sustainable solutions, and that current policies are not sufficient. We need new modes of governance that, more adequately than current governance approaches, deal with the complexity and unstructured nature of 'sustainability' problems and which involve a large variety of stakeholders. To this end, we have presented the approach of transition management, which is operationalised through transition arenas.

Transition management offers a new policy perspective that uses the power of both markets and planning, and is engaged with the establishment of new as well as with the change of old institutions. This approach implies a new role for governments that should engage societal alignment policies—aligning policies and policy goals to visions of sustainability through transition agendas and the use of process management. This does not render obsolete the use of regular policy instruments, such as regulation and pricing mechanisms, but says that they should be undertaken as part of a broader transitional approach that aims to anticipate and adapt societal dynamics to sustainability goals.

Transition management was adopted as Dutch policy in 2001, when five ministries started developing transition policies for mobility, agriculture, energy-supply and biodiversity. Currently, different transition arenas have been established, visions developed and agendas aligned. Also, a large number of experiments in all of these fields have been set out. For the coming years the achievement of real-life successes and a further deepening of the concepts of transitions and transition management will be crucial. In our view, transition management not only makes good sense but is also the only possible (and doable) way of achieving true sustainability benefits in the long term while maintaining short-term diversity. The implementation of transition management, however, is dependent on factors such as creativity, perseverance, communication skills and spirit, and its success will therefore depend on those who take up this challenge.

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Chapter 11

DISCUSSION & CONCLUSIONS

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Abstract: This chapter summarises and analyses the contributions made in this volume about disciplinary perspectives on industrial transformation research. In particular, it explores the extent to which this knowledge may be deployed for the purpose of integrated policy-making towards sustainability and identifies research gaps that need to be addressed to improve the science-policy link. The main argument is that each discipline can make valuable, albeit partial, contributions to transformation research and policy. How those contributions are taken up and acted upon by practitioners will depend upon the perspectives, interests, capabilities and capacities of different stakeholders. We conclude by looking at some of the challenges ahead and how the disciplines may contribute.

Key words: industrial transformation, policy-making, sustainability, disciplinary knowledge, global environmental change, systems change

1. INTRODUCTION

What did we want and why?

The IT Science Plan distinguishes three major aims of industrial transformation research (Vellinga & Herb 1999):

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Xander Olshoorn and Anna J. Wieczorek, Understanding Industrial Transformation: Views from Different Disciplines 207–223.

– To understand complex society-environment interactions;
– To identify driving forces for change; and
– To explore development trajectories exerting a reduced burden on the environment.

The first inference is that industrial transformation research comprises changes in production and consumption systems, including incentive structures and related institutional settings. The second implication is that IT research is not constrained by disciplinary boundaries. It builds on the foundations of a range of social science disciplines including economics, sociology, psychology, human ecology, anthropology, political science, geography, and history, as well as on the foundations of natural sciences including physics, chemistry, biology, and technological sciences (Vellinga & Herb 1999).

We observed that the ideas central to industrial transformation are typically a subject of research in more transdisciplinary traditions, such as STS (Science, Technology and Society), management and innovation studies. More traditional disciplines like psychology or law have not adopted industrial transformation as a research subject. Nevertheless, by looking at related elements – human behaviour or legal questions, for instance – these disciplines contribute a wealth of ideas essential for a better understanding of how social change takes place and how societies influence these. The result is that research relevant to industrial transformation is not always well-structured, but remains quite scattered, operating at various conceptual levels, and with a fragmented terminology.

Given the need to structure, articulate and provide some scientific underpinning for IT research, we thought it would be useful to elicit disciplinary perspectives on industrial transformation. We also wondered about the inclusiveness of current IT-related research. The first working title of the book was a question: 'Industrial transformation research: what is missing?' A more specific question was: To what extent do the views of different disciplines on industrial transformation relate to each other? Do they contradict or mutually reinforce each other?

We think answers to these questions are relevant not only to the IT programme of IHDP but to formulating targets and instruments for achieving sustainable development.

How to analyse the contributions?

If the purpose of industrial transformation research is threefold, as suggested above, one might try to analyse how each discipline contributes to each specific purpose. As IT advocates a systemic change in production, consumption, the incentive structures and institutions, it is also possible to look into how such 'system innovations' take place and what drives these changes. A third possibility, that combines these two, is to look at the various mutually-intertwining life domains (social, institutional, technological and economic) that need to change towards more sustainable ones, and use the three purposes of IT research as cross-cutting themes for analysing how a discipline understands each domain. In any case, while crossing disciplinary boundaries, nothing remains black and white. For an economist, technology is part of an economy, as is society. Psychologists look at problems through the prism of human behaviours. Each discipline looks at life from a different point of view, starts from the frame of specific assumptions about what is important, and produces findings that may be broadly applicable or very specific to problems. Even if views from each perspective meet at certain points, they remain embedded in different perspectives in terms of foundational assumptions, key concepts, theoretical models, research methodologies, and so forth. This diversity needs to be treated as a potential strength, but we must beware that it can also be the source of considerable weakness. In this concluding analysis we will try to understand and respect disciplinary positions, and explore to what extent they are comprehensive, complementary, and how they can contribute to bringing about a deeper understanding of processes of industrial transformation.

2. ANALYSIS AND CONCLUSIONS

Below we present an overview of the main findings and insights of the various chapters and we shortly analyse their contribution to the industrial transformation.

The book begins with a chapter about individuals and their behaviour - perhaps reinforcing the view that society is made up of individual entities. The first chapter – 'A psychological view of industrial transformation and behaviour' – quickly introduces the converse view, namely, that individual behaviour is the result of society, *i.e.* culture and artefacts. It says that an individual (*i*) holds values (or goals), and (*ii*) is aware of its environment (perception), (*iii*) that values and awareness are determined biologically and socially, and (*iv*) that behaviour is an individual's striving for a fit between his/her values (or goals) and his/her perceptions or awareness.

De Boer considers that, roughly summarised, human behaviour is rooted in both biology and culture. The main opportunities to change human behaviour in more sustainable directions are found in the social domain, by influencing values and/or awareness. One must reckon, however, with biological constraints to the scope and the modes of such change.

De Boer concludes that the opportunities to influence behaviour are wider than commonly thought by non-psychologists, who, for instance, might feel that a change in some particular behaviour implies a hard-to-bring-about change in culture. He stresses that the design of effective policies to influence behaviour requires a clear specification of the change required. Two key factors are:

– Achievement of specific policy objectives can be aided or hampered by appeals to values within the broader culture;
– Effectiveness of interventions will increase if all the influences on a particular behaviour point in the same direction.

In sum, the effectiveness of policies depends on the extent to which they comply with human nature, so their design requires insight into this last.

There are several implications for stimulating industrial transformation from a psychological perspective. When IT requires a behavioural change it is first necessary to specify discrepancies between current and desired practices as a starting point. What is important to policy makers is that interventions should be developed and implemented in close cooperation with the people involved and affected.

The notion that individuals' values and awareness have social roots provides the bridge to the second chapter, 'Sociological perspectives for industrial transformation.' There, Mol and Spaargaren offer a selective review of the sociological literature that is relevant to the study of industrial transformation. They start by pointing out that transformation and change lie at the very heart of sociology. The problem, however, is that over the years it has experienced a number of competing and conflicting schools of thought, different approaches, methodologies and interpretations of similar social processes. The authors observe that most of the social theories that have been developed within sociology give only an implicit account of the significance of the physical world within which the social occurs. Sociology is still struggling to integrate the social and the material into one picture, although this situation is changing. For instance, the phenomenon of *environmental sociology* dates back only to the 1970s and the rise of modern environmentalism.

What can sociology offer industrial transformation? Mol and Spaargaren observe that general sociology tends to be mainly of a descriptive character: it seeks to understand and interpret social change. It identifies the consequences of specific transformations for the properties of modern societies, and refrains from being normative and prescriptive. This is, to some extent, at odds with IT research, which explicitly wants to be goal- and action-oriented. On the other hand, one of the purposes of IT research is to comprehend the nature and drivers for social change better. For theoretical sociology, the vital element for developing policy on environmental issues is not the actual decision-making as much as the forging the participatory frameworks that will lead to policy results.

Current environmental sociology attempts to include material flows (*e.g.* emissions, use of material resources) as a research subject. Network modelling is one of the ways to combine sociological and physical descriptions, since sociological models of networks — social systems in which actors (or agents) interact according to certain rules (or institutions) — have the structure and properties similar to material flow models. Mol and Spaargaren feel that sociology of networks and flows is most promising in terms of sociology's contribution to IT research.

Gupta's chapter on 'Industrial transformation and international law' is, in a way, about networks, actors being countries and rules being international law. Gupta considers network dynamics, viz. the way that international (environmental) law changes in relation to changes of actors (*i.e.* changes in domestic law). This is obviously important to industrial transformation, since law is a vehicle for the implementation of moral principles, such as the need to preserve the integrity of the world as a life-support system. Gupta gives brief histories of International Water Law, the Law of Sustainable Development, and the United Nations' Framework Convention on Climate Change (UNFCCC). She draws a distinction between international law slowly emerging out of the past (incremental change), having its roots in pre-modern legal arrangements, and international law that addresses hitherto unknown problems (such as the depletion of the ozone layer, climate change) by sometimes new institutions and juridical instruments — emissions trading, for example.

The explanation of how law is created and develops differs depending upon the nature of the law. Gupta describes one mechanism in some detail: regulatory competition. This mechanism refers to adjustments made to (environmental) law as an instrument to attract foreign investment. Such a mechanism may lead to further adaptations of environmental standards. Depending on the weight that foreign investors attach to environmental standards, such a process can be directed downwards (a race to the bottom) or upwards (a race to the top).

Even though industrial transformation is not a core focus in law, a better understanding of the legal dynamics allows for better applications of the law as a tool to influence industrial transformation. When stimulating change of the legal incentive structure, policy-makers need to bear in mind that law has significant potential for promoting transformation, influencing state and human behaviour through normative force, incentives, rights, responsibilities and penalties. It also provides judicial remedies for possible future "wrongs" that may be caused in the process of change – for example, the no-harm principle and liability at international level — this provides incentives for taking preventive and precautionary action.

On the other hand, there are limits to the law's ability to provide incentives for social change, for a couple of reasons:

– It may limit the speed of change to what is constitutionally acceptable or in line with the rule of law - law is inherently conservative;
– It is deeply rooted in sometimes divergent national customs before being codified;
– It is reactive to problems; and
– Legal principles may be of an open-ended nature.

At the same time, Gupta imparts some optimism by saying that because international law is often far less mature than national legal systems, there are opportunities to generate incentives for industrial transformation at a global level along with the process of developing international law itself. The precondition is a better understanding of the manner in which norms develop and where the possible points of intervention are.

The big gap in transformation research from a legal perspective is that, according to Gupta, while new legal tools are being developed to deal with new legal problems, there is limited theory-forming in the area of international environmental law, limited empirical research on international environmental law issues, and limited analysis of the role of norms in shaping international agreements.

Law is an outcome of politics. Chapter 5 indicates what political science can also contribute to our understanding of industrial transformation. Jacob *et al.* start their extensive review by considering research on international polity regimes. They put forward two methodological issues that are debated in current political science of international governance: *(i)* what is institutional effectiveness; and *(ii)* how to theorize global governance? One of the empirical results mentioned is that diffusion — or globalisation — of national environmental 'successes' does not necessarily need to be enforced by strong international institutions. States can and do learn from one another, and emulate one another. This encourages national efforts towards industrial transformation. Jacob *et al.* seem to be more optimistic than Gupta about the outcome of the process of regulatory competition (*i.e.* globalisation). They continue by presenting an analysis of the typical history of post WW-II environmental policy-making in highly industrialised countries.

They conclude that current national environmental policy-making in industrialised countries is undergoing two kinds of change. Firstly, there is a general impression that some environmental problems require fundamental structural changes and considerable technological innovation. Existing market-based and self-regulatory instruments therefore prove to be insufficient. As a result, innovation and integration of different policy domains that provide a long-term perspective for industrial restructuring have become real challenges for environmental policy. Secondly, regarding the shift in emphasis mentioned above, greater numbers of actors are becoming involved in environmental policy-making: environmental governance has expanded both in terms of the number and involvement of stakeholders. These conclusions accord with what IT advocates.

Jacob *et al.* close their chapter with a call for a globalisation of political science research. The need to undertake a *world environmental policy* implies not only considering all world regions analytically, but also an internationally-concerted effort to make use of the comparative advantages of the local knowledge of particular regions and processes. This calls for diversity within the research community, together with stronger networking applied also to the sub-field of political science.

The foregoing chapters on sociology, law, political science and psychology, clearly show the historical nature of these disciplines. This contrasts with the more ahistorical approaches of economics, as shown in the next three chapters.

Olsthoorn and Kuik consider ecological economics as a rather open field that connects economics with perceptions — assessments — of the natural (environmental quality, resource base). Ecological economics is one of the foundations of the IT research programme. Ecological economics is part of the discourse that justifies efforts to bring about industrial transformation. Ecological economics is functional in at least two ways:

- It proposes indicators that can be used to gauge environmental quality, or other essential properties of the environment. For IT policies it is important to be able to rely on robust indicators; and
- It criticizes and complements mainstream economics. For instance, ecological economics points at the finiteness of resources and the risk of destabilizing the biosphere. It is possibly even more important that ecological economics has broadened the perspective of economists and the scope of mainstream economic analysis.

In sum, ecological economics articulates concerns about our environment. Neo-classical and evolutionary economics are instrumental in addressing the question about what to do about these problems.

In their review of evolutionary economics and industrial transformation, Van den Bergh *et.al.* analyse policies to influence consumer behaviour and innovative behaviour by firms. The policy-making lesson for evolutionary economics derives from its analysis of the behaviour of economic agents. This analysis is prompted by shortcomings[30] perceived in the neo-classical economic view of economic behaviour, in particular with respect to firms'

[30] *I.e.* difficulties in developing models that can adequately simulate economic behaviour.

investment in invention and innovation. Neo-classical economics is limited to examining the conditions for reaching equilibria in the use of available resources against given objectives. It does not explicitly consider the mechanics of change towards such equilibria, or the nature of the processes that occur 'within' and among economic agents, whereas evolutionary economics does. The adjective 'evolutionary' suggests that technical change is considered as a Darwinian process[31] (early economic analysis of technological change, notably by Schumpeter, did not connect this directly with Darwinian evolution). Against this background, evolutionary economics has the following lessons for government to facilitate industrial transformation:

– Give room to and foster the birth of a variety of infant technologies that would comply with IT goals by, for example, maintaining a range of basic and applied R&D activity, and stimulating deviations from habitual and routine behaviour;
– Enable technologies to become mature in niches, *e.g.* by stimulating learning and public demand; and
– Foster the rate of inheritance — the adoption of new technologies — by stimulating processes of imitation, possibly across sectors. Some important instruments to achieve this are education and regulation.

Van den Bergh *et al.* close with the remark that further research is needed to arrive at more specific and operational policy conclusions.

Den Butter and Hofkes developed their paper from the economic justification of government intervention, whose assignment is to counter market failures. They first explain that neo-classical economics views environmental problems as a problem of market failures. Therefore, the government is authorized to implement an environmental policy. Policy instruments range from taxes, subsidies, tradable permits, direct regulation and voluntary agreements, in relation to the nature of market failures (they differ according to the natural environment that is considered).

The second part of the chapter concerns ways of modelling technical change. The trick for introducing history into neo-classical equilibrium modelling is to use a vintage model. Through modelling, neo-classical economics can explain technological lock-in in terms of informational deficiency and inhibited learning processes. This justifies a governmental effort to promote learning (*e.g.* through consumer awareness campaigns). Den Butter and Hofkes notice that technological knowledge, at least partly,

[31] In other words, technical change is modelled by a genetic algorithm, which is a search (*e.g.* of an optimum) algorithm based on the mechanics of natural selection and natural genetics. The search is guided by historical information on the fitness of a preceding generation of solutions (phenotypes) to its environment.

has the character of a non-rival public good. Therefore, in the market there is too little investment in the production of knowledge, since not all revenues of knowledge production will accrue to the investor. So, it is good public policy to subsidise the investor *in spe.*

In sum, the government should understand that the diversification of new technologies can be hindered by capital market imperfections, and that societal costs with respect to environmental preferences can play a major role in the adoption of new technologies. Therefore, the lesson of neo-classical economics for industrial transformation is that effort must paid to co-ordinating environmental and technological policies. According to den Butter and Hofkes, government should leave decisions about the actual development and adoption of new technologies to the market.

We note that industrial transformation is, by definition, about systemic change. The assumption is that a sustainable future will differ deeply from current society. Given this view, both neo-classical and evolutionary economics advise only marginal changes. Models of current economies give *ceteris paribus* policy advice only. They do not account for changes in preferences, worldviews, politics or other deep changes in society.

If in searching for sustainability we limit ourselves to formulating short-term goals — *i.e.* those not requiring systemic change — economics can provide robust advice for public policy-making. This advice, however, will refer only to the economic efficiency of reaching normative goals, given the current situation. For instance, feelings of injustice (or equity) that are involved in political decision-making are not considered in economics (unless converted into economic terms). When considering how such matters play out in society, we must return to sociology and political science.

The one truly multi-disciplinary chapter — 'Multi-level perspective on system innovation' — draws on a variety of research traditions to construct a generally-applicable framework to describe system innovation. The subject is transitions from one socio-technical system into another. The concept of *socio-technical system* expresses the idea that the shape and use of technical artefacts is embedded in social processes and stuctures. The multi-level perspective (MLP) is a concise analysis of the stability of such systems. Stable elements of these systems are called the socio-technical regime. The set of conditions beyond the sphere of influence of the actors within this regime is called the socio-technical landscape (the macro level). And the seeds of change germinate and are nursed in niches (the micro-level) at lower levels of the system.

The MLP distinguishes between the many actors and mechanisms that are at work, and concludes that change results from the interplay of many processes and actors across levels. On the prospect of being able to alter a socio-technical regime, Geels calls for modesty. Synoptic planning of technical change is doomed to fail; he calls for interactive policy-making and learning-by-doing strategies. Geels draws several conclusions. With respect to innovation policies he mentions several ways to *(i)* expand the range of applications of novelties and *(ii)* to foster creativity, echoing the conclusions of van den Bergh and colleagues. With respect to research, he identifies — and briefly summarises — several possibilities to improve both the conceptual and empirical basis of the MLP.

The final chapter, by Loorbach and Rotmans, is 'Managing transitions for sustainable development.' This chapter presents the policy analysis that was adopted by the Dutch government in its efforts to address the *wicked* (OECD, 2001) environmental problems (see also the chapter by den Butter and Hofkes). This 'transition management' framework draws heavily on an analysis of technological change presented by Geels, and was a major element of the policy narrative of the Dutch government's transition policy, adopted in 2001 in its fourth national environmental policy plan (NMP4, VROM, 2001). This policy plan sets out the goal of bringing about transitions that take a period of typically 25 years, given '…goals or visions of the end state that guide public actors and orient decisions of private actors.' The practical management of a desired transition proceeds by repetitively executing a cycle of four steps: *(i)* creating a 'transition arena' - a forum for stakeholders in the transition process; *(ii)* initiating and sustaining a process for creating visions and agendas; *(iii)* implementing 'transition experiments'; and *(iv)* monitoring and evaluating the efforts and their results in order to start a new round. The last step - considered a key step in the process of social learning - implies a concrete change in the governance of the transition. As such, Loorbach and Rotmans introduce both a multidisciplinary and practical effort to bring about industrial transformation.

All of these contributions are useful, but we should not expect developments in each discipline to adopt industrial transformation as a major influence on theory and research agendas. Each discipline will develop its own agendas in the future. For lawyers, sociologists, economists, psychologists, political scientists and systems analysts who remain interested in contributing to the interdisciplinary project of industrial transformation, what lies ahead? How can they contribute to the challenges to come? In the following section we raise some of the challenges confronting future practice and research. As such, this section leads towards our conclusions, where we consider the contributions each discipline can make towards this future research agenda.

3. THE MANAGEMENT OF CHANGE: SOME CHALLENGES AHEAD

The insights from research on industrial transformation are prompting a rethink about the ways traditional technology policy activities can be brought together for sustainable development. These include science and engineering R&D, regulation, marketing, foresight, networking and fiscal policy. The Dutch effort presents a first example of such rethinking resulting in a concrete transition management policy.

There are a number of appealing features to this rethinking. First, transition management draws upon a rich multi-level conceptualisation of socio-technical change, allowing the incorporation of multiple perspectives. Second, transition management has ambitious sustainable development aspirations, with nothing less as its goal than the instigation of step changes in the satisfaction of human needs. Third, transition management is practically oriented and pragmatic — it promotes the creation of 'sustainable' niches as sites for developing experience. Fourth, transition management emphasises learning processes. These niches will be experiments and catalysts for change, with an emphasis on processes of knowledge-creating and adaptation. And, fifth, transition management aims at being participatory. Social actors from beyond the conventional technology development nexus are brought more explicitly into innovation processes. In all these respects, transition management is to be commended.

Clearly, transition management holds aspirations similar to the three major purposes behind industrial transformation research, which introduced this chapter. Each of the disciplinary contributions summarised above has offered clues for developing that research. Psychology reminds us to pay attention to the person-environment fit when seeking to encourage change. Sociology points out that change proceeds through networks of people, artefacts and materials. Legal mechanisms are one way of requiring and enforcing change, although it is argued that legal change can be a slow and conservative process. Policy-makers have other means of influencing change beyond the law at their disposal. Contributions from different economic perspectives (ecological, evolutionary, and the neo-classical) explore how incentives influence activity and provide rationales for greater, more positive policy interventions in market failures.

Those features identified as necessary for industrial transformation, which make it so appealing and persuasive as a project, are, paradoxically, the same as those that pose the greatest challenges: wide participation, experimentation, action across multiple levels, instituting social learning, and coordinating many different social and technical processes. Here we will flag a few of those challenges: *(i)* the levels and contexts under which transformation is organised, understood, and takes place; *(ii)* the human values, consensus and dissent concerning visions for the best direction for long-term industrial transformation; and *(iii)* the significance of time in future analysis and governance.

Levels and contexts

In the case of transition management, industrial transformation is advocated through a process driven by innovative niches influencing incumbent regimes, which in turn are embedded in a social landscape. In so doing, there is a risk that processes of change that operate in other directions become under-emphasised. Do changes in the socio-technical landscape, for example, create opportunities for niche breakthroughs? How do processes such as shifting public values, say, or reforms of economic structures, permit niches to challenge incumbent regimes? In some circumstances, challenges from other regimes might present pressure for change. How might such interactions play out in practice?

Industrial transformation research does recognise that there are many different processes at play, operating at different levels (niche, regime, landscape), and deriving from different social domains (the state, markets and civil society). Less clear is how to really get to grips with an analysis of these complexities. Under which circumstances do given patterns of interaction facilitate or retard niche breakthroughs? In short, how can change processes come together to generate selection pressures that prove positive for niches that are sustainable? These questions are easy to raise, but very difficult to answer.

In practice, socio-technical regimes are under pressure from all directions, but some forces will presumably be stronger and more coherent under certain circumstances than others, *i.e.* depending upon the context. Adaptation to these 'selection pressures' may be possible using functions[32] already available to the network of incumbent regime members (*i.e.* internally), or if adaptation functions external to the regime may be required. Industrial transformation research maintains the possibility of co-ordinating selection pressures towards a sustainable development goal, and using niche-experiments to build up adaptive capacity.

[32] Understood as the degree to which new knowledge, search directions, supply of resources, the creation of positive external economies, and the formation of new markets happen through networks associated with the incumbent regime, or through processes external to the incumbent regime. Adaptation can be positive, in the sense that change is embraced, or negative, in the sense that change is resisted.

Perhaps one way of finding a way through the complexity is to develop a more contextualised understanding of 'transformation.' Are all transformations purposive, niche-originating transitions (like transition management), or might they be better understood as following different patterns of change, depending upon selection pressures and adaptation combinations? Some way has to be found to organise our understanding of the different processes, so we can get a better handle on when different types of intervention are appropriate under different contexts (in markets, by networking, or through hierarchies). The challenge ahead is to identify the connections and general patterns that are characteristic of a transformation process under a specified transition context. An analysis of the different contexts under which change occurs could contribute to the development of transformation research, perhaps leading to a robust typology of transition contexts and transformations to aid future analysis and policy development.

Human values, consensus and dissent

Industrial transformation research seeks change in the systems that satisfy human needs for housing, mobility, food, health, and so on. The transition management contribution envisages this systems innovation building upon growth in niche-based sustainability experiments. Yet there are many definitions of sustainability. It is an essentially contested concept. This is "…a strength since it creates debate, necessitates continuing reflection, requires us to sift evidence from rhetoric, emphasising the importance of being explicit about what is being sustained, for whom it is being sustained, how it will be sustained, and why it should be sustained for them" (Berkhout, Smith and Stirling, 2003; 2004). A corollary of this is that transformation research will require a similar discipline regarding the types of transformation being analysed or promoted, and the kinds of sustainability vision underpinning them. This is especially true since transformation needs active processes of consent-formation in long-term goal setting.

A key device for driving change — long-term goal setting — remains relatively under-developed. The task appears to be to put in place those functions necessary for progress toward the guiding vision. These functions require the resources and consent of diverse sets of people. The way this happens in practice may depend, in part, upon the prevailing political culture (a 'landscape' variable). Research into social choice suggests that would be ill-founded to assume too much about an obvious 'guiding vision' for the 'public interest' or 'common good' (Arrow, 1963). It is sufficient to point out that, given the contested nature of the transformation goal (sustainable development), different groups in society will hold different visions of the future, and that these groups and visions will change with time and experience. Psychology may indeed help us to explain these differences and understand these processes of consent-formation.

There may be common elements of agreement between visions (perhaps over the generalities), and there will be areas of disagreement (such as on some of the details). Not all of these 'visions' will be expressed in the form of a coherent socio-technical regime or the construction of experimental niches. Some will; others will be directed more in the form of a critique of an existing or emerging regime (such as GM food), or advocacy of changes at the level of the socio-technical landscape (such as exercising the precautionary principle in regulatory policy decisions). However, at some point industrial transformation will not only need to build such views into some form of consensus, but that consensus will also need to be translated into a set of specific experiments and activities. Consensus might be built by permitting a diversity of experiments, each encapsulating a slightly different vision of sustainability. There is a sense in which this happens already on a smaller scale. Take housing as an example. Mainstream housing providers are moving in a 'light green' direction through experimentation with higher insulation levels, perhaps the installation of grey-water recycling, and even some embedded renewable energy. Meanwhile, a more radical niche of eco-housing builders is experimenting with more radical housing designs that utilise local materials, which are super-insulated, heated through passive solar design, and constructed with high user involvement, perhaps even self-built. Each set of experiments claims to be moving towards a more sustainable future, but the vision of that future is different. Somehow, industrial transformation needs to harness that diversity.

Significantly, the groups advocating different visions will be resourced differently; their ability to raise expectations and attract others to their views of the future will be different, and they will exert different degrees of economic and political influence. Political science offers perspectives on this coalition-building.

The reflexive orientation of transformation research means that guiding visions remain provisional and subject to review. Institutional investors, amongst others, might prefer stronger, more confident expectations when deciding upon which visions to invest in. Of course, this caution might be mitigated through schemes to underwrite financial risks. Either way, the mobilisation of large amounts of capital has somehow to be facilitated as an integral part of any transition strategy. How do we balance a reflexive modulation of visions whilst nurturing long-term investment in change?

While researching techniques for building consensus and coalitions, however, we also need research into the (positive) role that informed dissent can play as a driver of innovation and change. A functionalist tendency in industrial transformation might view conflict as problematic for the smooth transformation and operation of the system. In practice, change is unlikely to be so smooth. To what extent, for example, did a noisy ecologist vanguard contribute to green knowledge-making, and precede the development of the environmental management profession that we work in today? In which arenas does protest (be it from environmental NGOs, business, unions, or communities) actually further knowledge about 'sustainable development'; and how does this sit in relation to more co-operative modes of governance that demand compromises? Looked at from this perspective, the challenge is not so much to understand consensus-building, but rather to analyse the diffusion of novel and challenging ideas into mainstream thinking and practice. There is scope here for disciplines like sociology to make their contribution felt.

Time scales in transformations

Industrial transformation is a long-term process – it anticipates a 25 to 50 year timescale. The interconnected changes along the way arise through processes that have different tempos and rhythms. Many interdependent, yet contrasting, timeframes will be involved in such system transformation. It is worth noting that this book's contributions have not analysed time as an important variable in connection with these issues. Pressure for change, for example, comes from environmental considerations like climate change, whose impact takes many decades to manifest itself and could endure for centuries. The (shallow) institutionalisation of this concern has taken decades[33] and still needs substantial deepening. The challenge is to incorporate the very long-term carbon cycles (and the other natural processes in which human society is embedded) much more forcefully within short-term decision-making.

There are other timeframes to be considered, too, including the business cycles of firms, payback periods, annual profitability pressures, depreciation of assets, and other time-bound criteria upon which firms base their decisions. Consumer attitudes do change with fashions and other trends. There are the lead times of technology development, and the different time-scales over which successful artefacts diffuse into mainstream use. The way social movements build and impact upon the landscape (or not), the political cycles of governments, the rise and fall of ideologies (like neo-liberalism) — all of these are relevant. Uncertainties become known risks as we learn about them and they are widely recognised. However, development also means

[33] The Intergovernmental Panel on Climate Change was created in 1988. The first Kyoto commitment period falls in 2008-12.

that new uncertainties open up. Again, these will have their own rhythms, pace and intensity. All are factors in transformation.

What are the critical pathways and actions that need to be scheduled? To what extent is this possible? Which processes can be accelerated, and which not? All analysis must include a fuller consideration of time. Evolutionary economics takes an explicitly dynamic view, and perhaps offers one perspective on history and the future that could be developed by industrial transformation researchers.

This chapter began with the three motivations behind industrial transformation research, namely:

– To understand complex society-environment interactions;
– To identify driving forces for change; and
– To explore development trajectories that place a significantly lesser burden on the environment.

A better understanding of differences in context, and some way of organising that context, is one way to develop research into complex and coupled society-environment interactions. Visions of the future and human agency have to be one of the future driving forces for change — although we must also acknowledge the impediments of social structures and power. Finally, the development of trajectories has a critical time dimension, in which contingencies come together, and interventions are anticipated and targeted to appropriate moments. These are some of the research challenges that lie ahead.

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EPILOGUE

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'*A system is just like truth's tail, but the truth is like a lizard. It will leave the tail in your hand and escape; it knows that it will soon grow another one.*'[34]

The motto of our book has a number of bearings to industrial transformation science: it says for instance that a scientist can only come to a partial understanding of industrial transformation processes. This is so not only because of the vastness of the topic, but because of the inherent limitations of each scientific discipline. The common ground, which scientists of different disciplines may seek to find when approaching some problem, is often slight. A scientist beginning such research runs the risk of getting lost, losing understanding and only catching the loose tail mentioned in our motto. Nevertheless, we believe there has been progress and that we have been able to describe some of the different tails of the industrial transformation lizard.

The motto also says, however, that the horizons beyond which scientists want to move may always seem out of reach. Industrial transformation towards sustainability is an unending process because social and industrial change is an intrinsic aspect of societies. This is good news for those seeking a career in IT research. However, to make a difference science must provide facts and arguments that are effective in the public domain of policy and

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[34] Ivan Sergeevich Turgenev (1818–1883), Letter, Paris, January 3, 1857, to Count Lev Nikolaevich Tolstoy. *Turgenev: Letters*, ed. David Lowe (1983).

opinion. To this end, the global environmental science community has created international institutions to coordinate and channel their activities. Global environmental research has been organised in four global environmental programmes: IGBP, IHDP, WCRP and Diversitas. These have made an effort to gather up existing knowledge for the purpose of understanding the Earth system better, and thereby providing a knowledge base for the design of more effective policies at the global, regional and local levels.

This volume and the process of preparing the book (workshop discussions and review of contributions) prove that it *is* possible, however difficult it may seem, to discuss the *environment* in multidisciplinary groups. Of course, one will never be rid of one's prejudices, and each process will be subject to the idiosyncrasies of those taking part in the process. But a certain disciplinary balance was achieved, and we drew some significant conclusions for policy-making and industrial transformation research. One of these was that there are limits to *transdisciplinarity*. Its scope will be circumscribed by disciplines that find it difficult to re-formulate their methods, terminologies and perspectives. Transdisciplinarity is not a goal in itself and should not become an obstacle to disciplinary research. Each discipline will continue to define its own research programme. Programmes like Industrial Transformation of IHDP are aimed at bringing together different, often conflicting, opinions, stimulating constructive dialogue, and linking science and policy. This intellectual exercise is part of the process of creating the common ground to more effectively deal with current environmental problems.