1. Conceptualizing, observing and comparing socioecological transitions

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1.1 INTRODUCTION

A transition to a more sustainable state of society and the environment, a perspective that envisages attractive human futures on a hospitable planet Earth – this is a vision that nowadays inspires much research and policy-making. The notion of transition implies a major change – not incremental adjustments or improvements, but a qualitatively new state of the system. Transitions of a different kind may well be under way already, however. Do we not experience a rapid, even increasing pace of change in our working lives, our families, many of our institutions, our technologies and our everyday culture? Do we not perceive rapid transformations of landscapes in industrial centres as well as in holiday resorts at the periphery? And do we not have the impression that the weather has changed compared with our childhood, invalidating old rules of thumb? On the timescale of human lives, which is the common timescale for comparing experiences, time does not stand still at all. It seems rather the case that people are finding it difficult to move as fast as the world around them.

The environmental historian, John McNeill (2000), addressed this phenomenon in the ironically titled publication, *Something New Under the Sun*, a review of the 20th century. According to the statistics he assembled, there is barely any dimension of human social life and interference with the environment that has not undergone a rapid expansion worldwide during this one century, an expansion that has exceeded the factor 5 growth of the human population, substantial in itself, sometimes by an order of magnitude.[1] In this context, what makes us believe that we exist in some steady state or equilibrium? How could we possibly not think that we are in the middle of a rather explosive transition?

Usually, 'transitions' are broken down into a formal sequence of phases that lead from a status quo state to a new equilibrium. A common distinction is made between a *take-off phase* (in which the status quo is still in place, but various symptoms of its initial destabilization are evident), followed by an *acceleration phase* in which many rapid changes take place and a subsequent *stabilization phase* in which those changes are slowing down and the features of a new equilibrium are beginning to crystallize. If the particles involved in such a transition had some consciousness, how would they feel during each phase? If we mobilize our empathetic imagination, we might conjure the following pictures. In the take-off phase, the particles would experience a destruction of order. To some of them, this would appear very threatening. To others, however, this might appeal as a form of liberation from traditional constraints. Some particles therefore would feel the need to fight in defence of that order, and some would organize to accelerate its destruction – controversies and struggles would arise. What then should we expect in the acceleration phase of a transition? The most probable mental state of the particles would be one of passivity: the feeling of being driven in some direction without having a chance to do much about it, except for remaining mobile so as not to be trampled in the process. Those who are further in front would appear to be faster, as leaders to be followed, and anyone slowing down would be kicked aside. In the stabilization phase, finally, one would expect there to be great insecurity as to what the new state was going to be like. Again, struggles might be expected to ensue over the features of the new order and the interpretation of experiences various particles have made.

If we take John McNeill's reconstruction of the 20th century seriously, we are neither in a stable status quo, nor in the state of a new equilibrium. If some of the conclusions from the classical Club of Rome study on the limits to growth (Meadows, Meadows and Randers 1972) may have been wrong, one presumption was certainly correct: we have just one planet at our disposal (so far at least). An ongoing explosion within the confines of a limited space cannot be described as an equilibrium, even, if we use the term 'dynamic' very liberally. At the same time, it is also hard to believe that we might still be in a take-off phase, since the entire past century was marked by such tremendous changes. It appears most likely that we are within an acceleration phase, in the middle of a transition. How far we still have to go in this acceleration remains unclear. Possibly, we are already close to a new equilibrium, since it is highly improbable that the socioecological regime we see now can continue for, let us say, another 200 years. The ongoing transition is bound to lead to some new, as yet unknown state. How pleasant this new state will be for humans remains to be seen and it is not known how quickly such a new equilibrium will be reached after a potential period of massive disturbances.

One may develop such a scenario regarding transitions from the vantage point of environmental history. The particular historian we refer to

(McNeill 2000) focuses on a large number of variables and on a time span covering centuries. Given another timescale, and using another selection of variables, other events may appear as transitions. The choice of timescale to be employed depends among other things on preconceptions concerning sustainability: if one feels a sustainable state of society and the environment is fairly close to where we are now, there is no need to discuss time spans of more than a few decades. If, however, one feels that such a state is significantly different from the present and will therefore take quite some time to develop – as the authors of this publication tend to believe – then one needs to look at larger time spans. The specific choice that moulds this book's approach involved analysis of a time span that looks back to the last major transition in world history: the transition from agrarian to industrial society. At various times, at various places and at various scales, we may observe different phases of this transition process, a process that is still ongoing.

1.2 A FAMILY OF TRANSITION CONCEPTS

A specific feature of transition is the idea that it lies between two qualitatively distinct states, and that no linear, incremental path leads from one state to the other but rather a dynamic, possibly chaotic process of change. Looked at from the inverse perspective, it is the particular methodological (even epistemological) achievement of the transition notion that it allows two qualitatively different states to be distinguished (naming them differently, for example). In comparison, theories of growth or modernization do not provide any order except for that defined by the time axis: one may refer to an 'early' or 'later' period for example, while still assuming a certain homogeneity of the basic setting, and gradual change over time.[2] The 'transition' assumption of discontinuities along the time axis, by contrast, suggests a change in the basic setting.

One has to be aware, however, that this perspective is extremely sensitive to the choice of scale. Consider the process of walking: from a wider perspective (in terms of time, say minutes, in terms of space, say landscape level), this appears as a continuous process, progressing in linear fashion across space, sometimes a little slower, sometimes faster. From a closer perspective (measured in seconds, with a spatial focus on the human body), it appears to be a cyclical process in which each leg is alternately lifted and set down on the ground. From an even closer perspective (measured in fractions of seconds, and observing groups of muscles) it would appear to be a transition process between one group of muscles contracting and then relaxing, and then another group of muscles in action. This demonstrates that transition theories and theories based on the assumption of gradualism do not necessarily contradict each other. One type of process may well be 'nested' within the other. These only compete when both types of theories are expected to explain a given phenomenon on the same spatial and temporal scale.[3]

Another ingredient of the transition notion is the idea of spontaneity or emergence: it is neither possible for one state to be deliberately transformed into the other, nor for the process to be fully controlled. Particularly if, as in sustainability research, the concept is applied to complex systems (such as societies or technology regimes), one is dealing with autocatalytic or autopoietic processes (Varela, Maturana and Uribe 1974) to which concepts of orderly governance, steering or management cannot be applied. It is commonly assumed, however, that the system's resilience is decreased during the take-off phase of a transition, when the old interrelations are breaking apart but no clear directionality of change has yet been established (Berkhout, Smith and Stirling 2003; Rotmans, Kemp and van Asselt 2001). This lack of resilience can present opportunities for competing forces within the system (as is assumed, for example, in Marxist theories), and it provides improved opportunities for systemic intervention. Systemic intervention takes into account the self-regulatory quality of complex systems, seeks to disturb them and cause resonance leading to change from within (for social systems, see Willke 1996).

Systems theorists have observed the phenomenon that complex systems, in particular ecosystems, may have a number of stable states or equilibria, that is, states of being to which the system will return after periods of disturbance (May 1977). When a system is moved beyond a threshold ('tipping point') it may rapidly flip from one equilibrium to another qualitatively different one – a process often described as 'regime shift', although other notions such as transition or transformation are also sometimes used. Systems are defined as resilient when they respond smoothly to gradual changes and return to their original state after disturbance. When approaching a threshold, however, a system is considered to be unstable, implying that it is undergoing rapid and largely unpredictable change. Small changes in conditions may then result in qualitatively different trajectories.

This concept, originally developed in general systems theory and often applied to ecosystems (for example, Gunderson and Holling 2002; Holling 1973; Scheffer et al. 2001), has recently been extended to socioecological systems, mainly by scholars assembled in the so-called Resilience Alliance (http://www.resalliance.org). Their basic concept is cyclical and may be summarized in the so-called 'lazy eight' diagram (for example, Gunderson and Holling 2002, p. 34). According to their view, change in ecosystems

(and socioecological systems) follows a four-stage scheme. A stable, highly connected, mature system state that may last over long periods is thought to be followed by three transient phases in orderly sequence that taken together may be thought of as a transition. First, long-accumulated capital (biomass in the case of an ecosystem) is 'released' in an act of 'creative destruction' (a term borrowed from Schumpeter 1950). Second, the system is reorganized, for example, through innovation or restructuring. In a third phase, the system is dominated by quickly moving 'pioneers' that are then gradually replaced by large, slow, highly competitive units that succeed in monopolizing resources and again build up large capital stocks of a new, highly connected and stable state. In the remainder of this book we choose not to distinguish these three transient phases largely derived from observations of changes in ecosystems, since for our purposes, the three-phase scheme outlined above (take-off – acceleration – stabilization) derived from a social-scientific perspective was felt to be more straightforward.[4]

In any case, this discussion shows that the way in which the overall process, and the relations between the stages distinguished and connected by transitions, are conceptualized may make a big difference. Processes in complex living systems are usually assumed to be irreversible, so there is a clear directionality of time. This directionality can either imply consecutive stages of a 'developmental' type (like ontogenesis, or Herbert Spencer's notion of evolution, or Marxist historical materialism), or it may instead comply with a Darwinian type of evolution, assuming the future to be contingent upon the past, yet principally unpredictable.[5]

In the first case, when a developmental conceptual model is employed, each stage necessarily follows from the previous one and is, as a rule, considered superior or more 'mature' (as an adult is more mature than a child). Progression to this more mature stage can only be accelerated or delayed and if the process of maturing is severely impaired or prevented altogether, some unhealthy, handicapped state or even decay of the entire system will ensue. Thus, there is no real choice as to where to go from state I since whatever action is taken, state II will follow sooner or later, unless the system dies off altogether.

In the contemporary family of transition concepts, quite a few follow this developmental, Spencerian conceptual model. This applies, for example, when the World Bank and OECD refer to 'economies in transition': this phrase denotes economies in transition from (presumably outdated) state-planned to liberal market economies.[6] Similarly, it is assumed in developmental economics that countries and world regions still relying on agrarian subsistence have no choice but to undergo a transition to industrialized market economies. This is substantially in tune with the 19th-century belief in socioeconomic progress as embodied in Marx and Engels' writings about the inevitability and superiority of capitalism over feudalism, even if it falls short of their subsequent argument about the inevitability of socialism. In such developmental socioeconomic theories, similar to child development, transitions occur according to an endogenous process and the built-in dynamics of the system itself. According to this approach, the social and also possibly the natural environment do play a role in providing more or less favourable conditions, but they are not the drivers of the ongoing dynamic process. Therefore, deliberative interventions into such a process only play a small role: they may remove internal or external obstacles to growth and maturation, or they may build up obstacles. There is no theoretical guidance for choosing or influencing the direction of the process: this direction is already deeply embedded in the process itself.

In the second case, when either a more Darwinian evolutionary model or unspecified, open-ended change processes are assumed, the task of intervening into transition processes becomes more complex as it also encompasses the choice of direction. Given the objective difficulties of analysis, there is always the temptation to suggest that the proposed direction is inevitable (as in the Spencerian mind model above). Historians who have analysed structural change in the past may find the subjective conviction of actors makes little difference: even humble conceptions of human governance over major historical change (which appears to be simultaneously over-determined and under-determined) seem in retrospect to be overstated. But for the contemporary citizen who wishes to orient his or her personal, political and economic actions in an appropriate way, the interpretation of ongoing change and its direction does make a difference.

Contemporaries of the 'great transformation' (Polanyi 1944) from an agrarian to an industrial society, in the 18th and 19th centuries, clearly tended to share the perspective on evolutionary progress and its necessity that we have attributed to Herbert Spencer above. This applies to Adam Smith, who in his *Wealth of Nations* (1776) interpreted all of human history teleologically as a mere prelude to the emergence of a capitalist liberal market economy (or the mode of subsistence 'commerce', as he termed the stage following 'agriculture'), seen as the final form of civilization realizing human nature. For Adam Smith, there was no doubt that 'commerce' was superior to 'agriculture', and that it would triumph by virtue of its own dynamics. Deliberative human intervention could only have the effect of either producing obstacles slowing down this process or of removing such obstacles.

Karl Marx also shares Smith's enthusiasm for the superiority of capitalism over the previous stage (as he termed it, 'feudalism'), as well as his conviction that capitalism would finally sweep away the remnants of traditional society. For Marx, though, human agency plays a much larger role. This

applies to the transition from feudal to capitalist society: even if the driving force in the background is technology (the 'development of the means of production'), it requires the bourgeoisie to be successful in class struggle for an actual breakthrough of the new social formation to be achieved. Equally, it requires not only the existence, but also the political organization of a new class acting towards the goal of overcoming capitalism. The next stage, socialism, would then be characterized not by the reign of blind market forces, but by collective human rationality and justice. This transition would not ensue mechanically,[7] nor could it be managed and controlled deliberately, but it would eventually come about as a result of societal struggles.

Nowadays, the discourse concerning a possible transition to a more sustainable form of society is no longer guided by trust in the iron necessity of progress. While a more sustainable society is generally considered superior to the current state, no strong impulse of history is felt that would take us there, whether we like it or not (Brand 1997). Nor are there highly organized conflicting societal forces that would drive this transition process. The transition to a more sustainable society is more a matter of reason than of passions, and certainly does not yet appear to be the logical and inevitable next stage. To many, though, it appears as the only plausible alternative to chaotic and possibly catastrophic developments of history. A sustainability transition is not conceived of as happening automatically, all by itself. It may only be brought about by deliberative human agency and this human agency may be organized in a variety of ways.

One approach towards understanding transitions, which focuses on the possibility of deliberative change towards sustainability, has been developed by Rip and Kemp (1998) and then elaborated by Rotmans et al. (2001) and Martens and Rotmans (2002). Their approach seems to have been fairly successful in informing and guiding the economic and technology policies of the Dutch government (Kemp and Loorbach 2006). The fundamental idea behind this involves exploring the possibility of technological change in certain niches, supporting seemingly more sustainable niche technologies by government policies and thereby hoping to stimulate a gradual change in the respective technology regime towards a new, more sustainable level. Berkhout et al. (2003) have elaborated on this approach by searching for 'quasi-evolutionary' ways in which technology regimes could be changed, not just through resonance on innovations in niches, but through policy interventions either via the 'selection pressures' on the regimes themselves (via energy taxation, for example) or via the 'adaptive capacity' of the network of actors collaborating within a technology regime.[8]

At present, this 'technological transitions' approach seems to be a politically operational strategy aiming to force technological systems towards sustainability. It is obviously more ambitious than mere attempts at cleaner production, even if those go as far as implying integrated process changes. This approach therefore comes closer to what we termed a socioecological transition (see below for more detail), but it still only deals with a fairly narrow range of variables. It distinguishes between three levels (micro – meso – macro). The micro level refers to technologies. The meso level deals with 'technology regimes' (which may in fact be several layers of nested regimes; see Berkhout et al. 2003) involving infrastructures, interconnected actors and financing systems. However, these notions of 'regimes' and 'regime change' signify societal features and changes less fundamental than our use of the term 'socioecological regime'. On the macro level, the approach talks about 'landscapes' to refer to a wider societal setting. While the original version focused mainly on a bottom-up transformation process (starting from the micro level with successful innovations in technological niches to then succeed in a gradual regime change, with resonance on the macro 'landscape' level), later criticism and extensions led to the specification of a whole variety of transformation processes, bottom-up or top-down, deliberate or spontaneous (Geels 2004; 2006). In all cases, though, this approach is restricted to time frames of no more than a few decades.

This book is based on a still more widely encompassing concept of transition – one that is focused on even larger time frames, from decades to centuries. We cannot easily deal with actors and their deliberate efforts on this temporal scale. The analysis focuses largely on structural change of interlinked social and natural systems. In theory at least, this refers to a much broader range of variables. In practice, though, we limit ourselves to a relatively narrow set, circumscribed by a particular paradigm as specified below, a set of variables localized at the society–nature interface for which quantitative measurements can be reliably obtained in very different contexts. The advantage of this self-restraint is that we can demonstrate the interconnectedness of (some) socioeconomic changes and (some) changes in natural systems very clearly, and thereby acquire the ability to model important necessities and constraints related to a sustainability transition.

1.3 CHARACTERIZING SOCIOECOLOGICAL TRANSITIONS

A socioecological transition, as we understand it, is a transition from one socioecological regime to another. How may we then define a socioecological regime? A socioecological regime is a specific fundamental pattern of interaction between (human) society and natural systems. To endow this sentence with meaning, we have to make at least a brief attempt to clarify the term 'human society' and to explain how it relates to natural systems.

(Human) Society and How it Relates to Natural Systems

How may we define a 'human society'? No clear consensus about this term exists, either within social science disciplines or between them. For the remainder of our argument, we shall need to relate human society (hereafter referred to as 'society', for brevity's sake) to its natural environment, or, in more fundamental terms, to nature. And we will also need to relate societies to one another. Exchanges with other societies may be functional substitutes for exchanges with a society's own natural environment, but this in turn has effects upon the other society's environment, so we shall have to be able to describe chains of effects across societies. Beyond that, we wish to be able to apply this term to human communities across history and around the globe.

In sociology, the term 'society' commonly refers to a social unit consisting of *a population within a certain territory, integrated by cultural commonalities*[9] as well as by political commonalities, such as shared procedures of decision-making, ways to enforce decisions, shared mutual responsibilities such as participatory duties, and a certain guarantee of care in the case of need (see, for example, Giddens 1989). While in sociology the idea of common governance (such as the modern nation state) is particularly important for the notion of society, cultural anthropology tends to stress the functional aspect of mutual interdependence and reproduction.[10]

For our purposes, this understanding of society makes sense. To conceive of society as a social unit functioning to reproduce a human population within a territory, guided by a specific culture, seems sufficiently abstract to be applied to different historical circumstances. It is still not very easy to determine the location of society in a hierarchy of social units (for example, household, community, state, federal state, the European Union or even the UN) or to determine whether American Indian kinship groups inhabiting a few settlements or different kinship groups meeting for winter camp, thereby providing an opportunity for culturally prescribed exogamous marriages, constitute a society. But perhaps it is not necessary to be precise at this point. What is more important here is to realize that society, according to this definition, links both elements that are symbolic, creations of social communication, and transmitted by communication between humans, subject to the rules of meaning and powerful for their meaning only ('culture'), *and* elements of a clearly natural origin and character, firmly subject to the rules of physics and biology ('population', 'territory'), in a way that has not yet been clearly specified.

If we turn our attention towards the 'idealist', 'platonic' tradition of the social sciences and look at the notion of society developed by the German sociologist Luhmann, we find that it is focused on communication, and on communication only. It appears devoid of any material, physical ingredients. Society, according to Luhmann, is the social system comprising all communication (Luhmann 1984; 1997). People, in the sense of physical persons, belong to society's environment, and so do all other material components such as habitat/territory, physical infrastructure or artefacts.

The power of Luhmann's notion of society lies in its consistent theoretical make-up. It is rooted in systems theory and rests upon a concept of the self-organization (or autopoiesis, that is, self-construction) of complex systems, and it invites us to think in terms of functional differences. Systems theory, we believe, provides a good basis for conceptualizing a world of meaning that is highly integrated internally and reproduces its boundaries vis-à-vis elements that do not 'fit'. This world of meaning and of communication is governed by completely different causalities (or interlinkages) than the material world. The grammar of a sentence is neither subject to gravity, nor to genetic transmission, the presence or absence of a 'minus' will make a huge difference that cannot be influenced even by an atomic bomb, and a 'thank you' may change an entire situation for years, independent of any change in ambient temperature.

Why should anyone interested in society–nature interactions find Luhmann's characterization of social systems as systems of communication that are completely devoid of biophysical characteristics an important theoretical tool? A brief answer would be: because it allows the systematic conceptualization of those features of human society that distinguish it from biophysical or 'natural' systems. In addition, it frames them in terms of a theory of complex systems formally developed in biology (for example, Maturana and Varela 1975). This theory departs from self-referential operations that – if operationally closed – lead to system formation, that is, to the establishment of a boundary between a system and its environment. According to Luhmann, in social systems these self-referential operations are acts of communication that establish, in a recursive process, programmes and codes that distinguish between functionally differentiated subsystems and build up a high degree of internal complexity.[11]

On the other hand, the price of this 'purity' of focus on symbolic communication is impotence in relation to the material world. How can a purely symbolic system make a difference in terms of influencing biophysical objects? The answer is that it cannot do so. An outside agent is required to 'reach over' into material affairs. It seems obvious that this agent can be, and indeed has to be, the human as a hybrid of both realms, a sharer of symbolic understanding and thus a communicator, and a bodily creature with the ability to undertake physical action. Thus, while we accept Luhmann's conception of autopoietic systems of communication as a valuable tool, this cannot be all there is to social systems, it cannot be all that constitutes society. For the purpose at hand, this term must not be deprived of all material meaning; society must not be so exclusively self-referential that it cannot move so much as a chair.

It does seem practical to distinguish between 'society' and 'culture', and to employ both notions. Thus, adopting Luhmann's system of communication for culture[12] and allowing society to retain some material features appears to be the solution that most suits a socioecological purpose, enabling us to look upon society as a hybrid of the realms of culture, of meaning, of communication and of the material world.[13] Society, according to our understanding (for more detail, see Fischer-Kowalski and Weisz 1999), comprises both a cultural system, as a system of recurrent self-referential communication, and material components; a certain human population; and – this is the core of our understanding of society–nature interrelation – a physical infrastructure (buildings, machines, artefacts in use and animal livestock). It is via these biophysical components of society that culture interacts with nature: they may influence each other only indirectly and always according to their own rules. Conceived in this way, societies are not 'systems' in a strict sense of systems theory. They consist rather of a 'structural coupling' of a cultural system with material elements.

The very term 'social' seems to bear this hybrid character. That something is social implies the involvement of human beings, and human beings as persons can also reasonably only be thought of as an interlinking factor, a structural coupling between a symbolic (cultural, cognitive, mind) system that follows its own processes of self-creation and maintenance (having sampled much of its contents from society's cultural system), and a physical system, a body (that derives much of its functioning from genetic information sampled from the population's gene pool). A household may be conceived similarly: it is probable that a family culture exists that guides behaviour, physical human beings belong to it, and other physical elements sustain it and are sustained by human activities, such as a home, furniture, pets, a garden, a car and so on. Obviously, the organization of the household is maintained by communication, but not by communication alone. It also requires certain purely natural processes (such as walls remaining upright, roofs protecting from rainfall, heating to retain warmth inside, dogs stinking, plates breaking, and so on), and, as a go-between, human labour that moulds material elements to reproduce household functioning.

To conclude, we conceive of society as a structural coupling between a cultural system and material elements, among them, as its functional focus, human population. Society is simultaneously guided by two programmes, two types of software: a cultural software (that determines meaning and moulds intentions) and a natural software that determines material effectiveness. Society has this in common with all other *social* units. It is distinguished from them by particular features, in which we basically follow the traditions most common in sociology and cultural anthropology (see above).

Society in its entirety may thus not be regarded as a subsystem of an ecosystem, as it is often conceptualized within natural science-based sustainability research (Berkes and Folke 1998). On the other hand, we do not underestimate the relevance of biophysical aspects or conceptualize social systems as devoid of any material, biophysical ingredients as is the case in much of the research produced in the humanities, sociology and economics. According to our understanding, society comprises both a cultural system, as a system of recurrent self-referential communication, and material components; in other words, a certain human population as well as a physical infrastructure that includes buildings, machines, artefacts in use and animal livestock, which in their entirety may be defined as 'biophysical structures of society' (Fischer-Kowalski and Weisz 1999; Weisz et al. 2001, p. 121).

As Figure 1.1 shows, this notion of society allows an epistemological framework for the interaction of social and natural systems to be specified. It comprises a 'natural' or 'biophysical' sphere of causation governed by natural laws, and a 'cultural' or 'symbolic' sphere of causation reproduced by symbolic communication. These two spheres overlap, constituting what are termed here the 'biophysical structures of society'.[14] According to this concept, the process of interaction between nature and culture can only occur via these societal biophysical structures.

Socioecological Regimes, History and Transitions

If society is a hybrid, comprising an autopoietic cultural system, and material elements to which it is structurally coupled, then the very interactions between society and its material environment should be of decisive importance for the development of society itself. This is indeed the core hypothesis of Maurice Godelier, whose work has influenced our understanding of the interconnections between society, nature and history. Godelier formulates his core hypothesis in the introduction to *The Mental and the Material* thus: '*Human beings have a history because they transform nature*. It is indeed this capacity which defines them as human. Of all the forces which set them in movement and prompt them to invent new forms of society, the most profound is their ability to transform their relations *with* nature by transforming *nature itself*' (Godelier 1986, p. 1).

This way of looking at history relates to the Marxist tradition but transcends it in an ecological, or co-evolutionary direction. The classic reading of Marx leads to a discussion of changing 'modes of appropriation of nature' through the development of new means of production, that is,

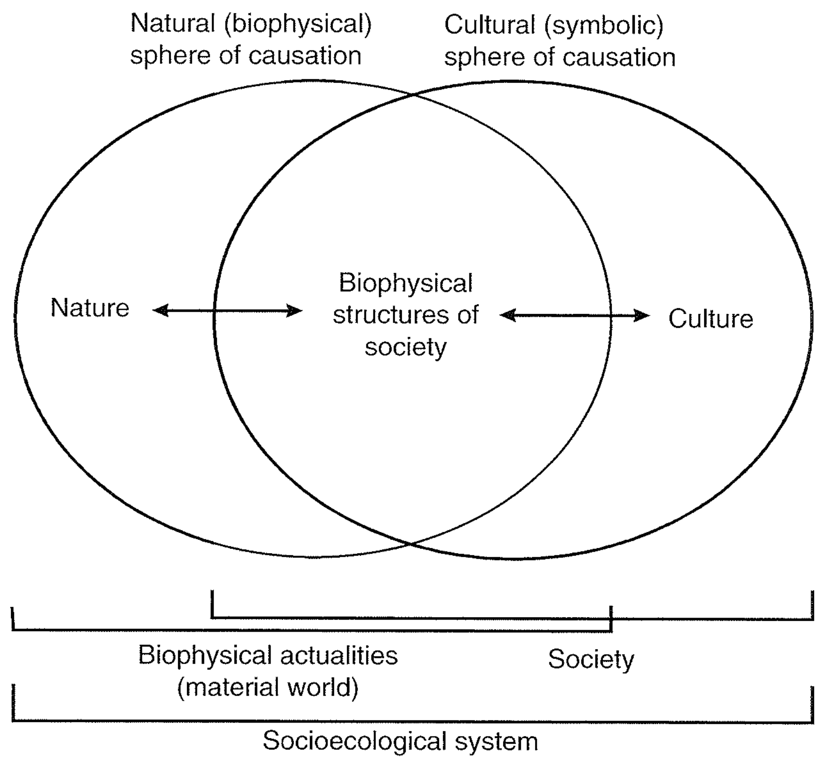

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Figure 1.1 Socioecological systems as the overlap of a natural and a cultural sphere of causation

technology.[15] Godelier's reading stresses the fact that human appropriation of nature modifies nature and this modified nature in turn stimulates social change. Godelier thus deviates from the common social science approach by viewing nature as historically variable, not as static, and his core hypothesis attributes societies' historical dynamics to a feedback process from nature:

> The boundary between nature and culture, the distinction between the material and the mental, tend moreover to dissolve once we approach that part of nature which is directly subordinated to humanity – that is, produced or reproduced by it (domestic animals and plants, tools, weapons, clothes). Although external to us this nature is not external to culture, society or history. It is that part of nature

> which is transformed by human action and thought. It is a reality which is simultaneously material and mental. It owes its existence to conscious human action on nature. . . . This part of nature is appropriated, humanized, becomes society: it is history inscribed in nature. (Godelier 1986, p. 4)

Thus, according to Godelier, the dynamic force in human history is not so much the dialectics of 'means of production' and 'modes of production' with nature as an external element, as something to be appropriated, but is instead the very interaction between social and natural relations itself.

If we now look upon society as reproducing its population, we note that it does so by interacting with natural systems, by organizing energetic and material flows from and to its environment, by means of particular technologies and by transforming natural systems through labour and technology in specific ways to make them more useful for society's purposes. This in turn triggers intended and unintended changes in the natural environment to which societies react. We regard this as a co-evolutionary process: societies become structurally coupled with parts of their environment, leading to a process where both mutually constrain each other's future evolutionary options.[16] The co-evolutionary process is then maintained by the specific exchange relationship with the environment, by the particular way a society interacts with certain natural systems. In this co-evolutionary process, we can distinguish ideal-typical 'states', that is, patterns of society–nature interactions that remain in a more or less dynamic equilibrium over long periods of time ('socioecological regimes'), and also periods of transition.

In the most general terms, socioecological regimes in world history correspond to what many authors, using different terms, have addressed as human modes of subsistence (Boyden 1992; Diamond 1997; Gellner 1988; Sieferle 1997b). The transitions between these modes of subsistence are so fundamental that they must often be called 'revolutions', namely, the Neolithic Revolution (the transition from hunting-gathering to agrarian society) and the Industrial Revolution (the transition from agrarian to industrial society). These transitions provoke a number of questions. Why did particular socioecological regimes not last forever, or, in other words, why were they not sustainable? Why was there, for example, a transition from hunting-gathering to the agrarian mode? And why, after roughly 10 000 years of agrarian societies, did a transition we call the Industrial Revolution begin, leading to another mode, which is still so dynamic that we find it hard to regard it at all as a defined mode of subsistence, that is, as a socioecological regime with some dynamic stability? And how does a possible future 'sustainable' socioecological regime that we might head for stand in relation to all this? These are wide-ranging questions indeed, and although we do not aspire to answer them in this book we do believe that they can provide the background needed to put the sustainability transition into perspective.

Looking back into history, we can also discuss the sustainability of previous alternative socioecological regimes. One of the most interesting discussions of this issue is provided by Sieferle (2003). According to Sieferle, hunters and gatherers sustain themselves through passive solar energy utilization, that is, their socioeconomic energy metabolism depends on the existing density of solar radiation and its transformation into plant biomass; they do not deliberately intervene in this transformation process.[17] Thus hunters and gatherers must more or less live on the resource density they find and as such, they can neither accumulate significant stocks of belongings nor seriously pollute their environment. The only sustainability threat they pose is in the form of overexploitation of key resources. For example, there is evidence that hunter-gatherers, although they probably consumed less than 0.01 per cent of the net primary production (NPP) of their habitat (Boyden 1992), contributed to the extinction of a significant part of the Pleistocene megafauna (that is, of animals with a body mass of over 10 kg, which were most suitable for hunting and therefore an important part of their resource base). Although the issue is highly controversial (Alroy 2001; Grayson et al. 2001), it does make a case for bringing the hunter-gatherer socioecological regime into debate, as far as sustainability is concerned. Nevertheless, this socioecological regime persisted for several hundred thousand years, certainly much longer than the prevalent industrial pattern, at least while it remains based on the use of fossil fuels and the large-scale use of exhaustible mineral resources.

Agrarian societies, to follow Sieferle, can be characterized by an energy regime of 'active solar energy utilization'. Their solar energy utilization is active insofar as they intervene into the solar energy transformation process by means of biotechnologies and by mechanical devices. The technological transformation of terrestrial ecosystems is of most importance: agrarian societies clear forests, create agro-ecosystems, breed new species and seek to extinguish other species. Their core strategy is the monopolization of area (and the corresponding solar radiation) for organisms with high utility for humans. Mechanical devices, on the other hand (such as the sailing boat or the watermill), transform solar energy occurring as wind or running water into a movement that can be utilized by humans.

Agrarian societies seem to have always struggled, with varying degrees of success, to maintain the delicate balance between population growth, agricultural technology, labour force needed to maintain the productivity of agro-ecosystems, and the maintenance of soil fertility (Netting 1981, 1993; Vasey 1992). Agrarian civilizations were always at risk, most often from a combination of technological and political dependencies and the fluctuations of natural systems. Not only did the ancient Mesopotamians gradually degrade their soils by irrigation techniques, forcing peasants at first to give up wheat cultivation for the more salt-tolerant barley and later to abandon cultivation altogether, but also medieval peasants in the Netherlands lost their fight against sand-dunes. Nevertheless, the agrarian socioecological regime, in many parts of the world, persisted for several thousand years and still persists today.

The presently dominant industrial socioecological regime dates back no more than 300 years and is based upon the utilization of fossil fuels. Its sustainability seems limited not only by the limitations of its energy resource base but also by the transformations it triggers globally in various life-sustaining natural systems. Today, Global Change research provides ample evidence that major human-induced changes can be found on any spatial scale, from local to global, and are transforming the Earth system at an increasing pace (Schellnhuber 1999; Turner et al. 1990). So this socioecological regime is bound to change as it erodes its natural base. In this situation, sustainability may involve guiding this transition within a corridor of acceptable quality of life, for present and future human generations. The MEFA framework as described below and referred to throughout this book is our core device for analysing and understanding the metabolic exchange relations between human societies and their natural environments, the feedbacks that transform both social and natural systems and the biophysical limitations of the systems involved.

The MEFA Framework for Describing Society–Nature Interactions

Current approaches towards analysing the biophysical aspects of the earth system (for example, Schellnhuber 1999; Schellnhuber and Wenzel 1998) can be traced back to the work of ecologists (for example, Lotka 1925; Lindemann 1942; Odum 1969) who conceptualized ecosystems using so-called compartment models. In these models, ecosystems are analysed by defining compartments, that is, black boxes transforming defined inputs into outputs, according to some internal mechanisms and depending on their own structure as well as on the state of all the other compartments of the system. Ecosystem research proceeded by analysing the physical stocks within and flows between the compartments and the mechanisms controlling these flows.[18]

Studying material and energy flows related to socioeconomic activities in a similar way as 'socioeconomic metabolism' can be traced back at least as far as this ecological research strategy (for reviews, see Fischer-Kowalski 1998; Martinez-Alier 1987). In the present context, the socioeconomic

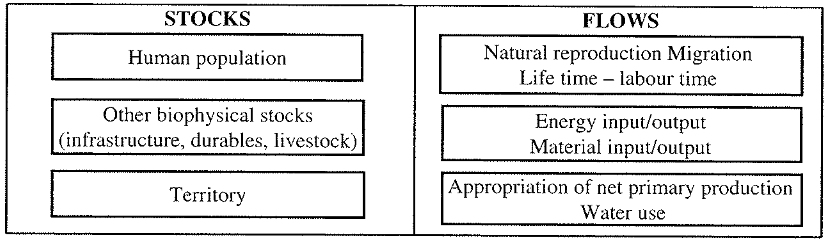


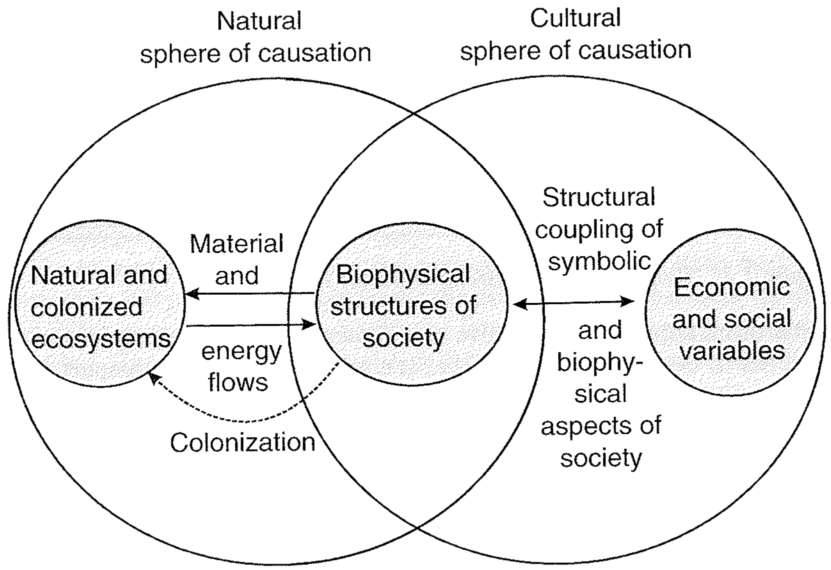
Figure 1.2 Biophysical dimensions of social systems

metabolism approach is attractive as it allows the biophysical structures of societies to be defined in a way that is compatible with the compartment models commonly used in systems ecology (Haberl 2001). That is, the metabolism approach allows one to analyse biophysical aspects of a society as if it were an ecosystem compartment, looking at its material stocks as well as the flows between the biophysical structures of society and the rest of the natural world. Generally speaking, the same concepts and methods can be used to deal with social and natural systems.

The stocks and flows listed in Figure 1.2 deliver a biophysical description of any society analogous to an ecosystem, and the interrelations between stocks and flows are – within a certain range – determined by natural processes. A description of these parameters is useful when analysing the interrelations and interdependencies between societies and their natural (and social) environments.

As a means of social science analysis, this is uncommon but hardly new. Anthropology, for example, has a long tradition of analysing the relation between simple societies and their natural environment by tracing energy flows (for example, White 1943; Rappaport 1971). Concerning complex modern societies, this approach can be traced back to the early 1970s (Ayres and Kneese 1969; Boulding 1973). It would not be as attractive, however, if it provided no more than a biophysical description. What it does in addition to producing biophysical descriptions is to establish a relation to the most powerful cultural system of modern society: the economy.[19] In particular, MEFA (material and energy flow accounting) seeks to analyse biophysical aspects of society in a way that is compatible with the most common and powerful tool for societal self-observation, the system of national accounts.

By means of this 'double compatibility', this approach establishes a link between socioeconomic variables on the one hand and biophysical patterns and processes on the other. Admittedly, MEFA remains an approach 'in the making'. It ultimately aims to provide a full systemic account of all the variables (and implied processes) listed in Figure 1.2 and their theoretical



Source: Reprinted from *Land Use Policy*, **21**(3), 199–213, H. Haberl et al. (2004), 'Progress towards sustainability? What the conceptual framework of material and energy flow accounting (MEFA) can offer', with permisison from Elsevier.

Figure 1.3 Biophysical structures of society simultaneously viewed as an ecosystem compartment and as structurally coupled with symbolic aspects of society

integration. What exists so far, and is utilized in the following chapters, is a sociometabolic model describing material and energy flows (see Figure 1.3).

Another set of relations listed in Figure 1.3 centres around territory and land use as one of the most important socioeconomic pressures upon the environment and driving forces of global change (Meyer and Turner 1994; Vitousek 1992). We have theorized this set of relations under the heading of 'colonization of terrestrial ecosystems' (Fischer-Kowalski and Haberl 1998; Haberl et al. 2001; Krausmann et al. 2003).

While socioeconomic metabolism refers to the exchange of energy and matter between social and natural systems, colonization refers to society's deliberate interventions into natural systems in order to create and maintain a state of the natural system that renders it more useful socially (Fischer-Kowalski and Weisz 1999). Thus, colonization refers mainly to human labour and to the information, technologies and skills involved in making labour effective. Within the MEFA approach, this theoretical concept has become operational in describing land use. Socioeconomic

land use can be related to changes in ecosystem patterns and processes. The impact of land use can be measured by comparing ecosystem patterns and processes that would be expected without human intervention with those observable in the presence of interventions. An example of this approach is the calculation of the 'human appropriation of net primary production', or HANPP (Vitousek et al. 1986).

Some other parts of the MEFA framework as outlined in Figures 1.2 and 1.3 remain very sketchy and will appear in this book only in rudimentary form. One of these still underdeveloped areas concerns population, its reproduction and time use. Yet another involves water availability and water use. MEFA does provide a consistent conceptual framework to deal with these issues and relate them to the other processes, but the provision of a comprehensive analytical and empirical body of research still lies some way ahead of us. In a similar vein, we have to admit to having made a largely descriptive use of statistical tools. Explicit causal models as well as uncertainty estimates shall constitute a next step in research terms.

1.4 THE DESIGN OF THIS BOOK

This book is an interim resumé of research carried out during the past decade by the team of the Institute of Social Ecology in Vienna, together with partners from all over the world. Within various contexts, more than 20 case studies were carried out that all follow the common conceptual and methodological framework referred to as MEFA in the preceding section. Regionally, these case studies range across Europe, India, Southeast Asia and Latin America. Temporally, some of them extend back over the past 170 years, others cover the past two or three decades, and still others refer to one or two points in time during the recent past. In terms of scale, they deal both with the local level (single communities) and the national level, and sometimes aggregate to regions.[20] Intellectual support in generating a coherent structure came from the International Human Dimensions of Global Environmental Change Programme (IHDP). Both the 'Industrial Transformation' (IHDP-IT) and the 'Land Use and Cover Change' (LUCC) sub-programmes endorsed our integrative research effort, in which we tried to build an umbrella over a number of cases, pursuing certain common research questions.

The point of departure for this research was the assumption that an eventual transition to a more sustainable socioecological regime would require as major a change as did the transition from agrarian to industrial society – a transition that is still ongoing in many parts of the world. Must it be assumed that the historical path will lead all regions of the world through a highly polluting and wasteful industrial stage eventually to some more sustainable regime? Would it not be worthwhile focusing attention on options of 'leapfrogging' certain developments? Since we believed that this should be considered, we wanted to attain a better understanding of what the agrarian socioecological regime entails and of what its potential for transformation is.

Another incentive for improving our understanding of the agrarian socioecological regime was the observation that several political demands from advocates of sustainability today provide reminders of the agrarian past, such as the appeal to return to biomass as the major source of energy, or the proposal that we should rely more on local resources and strengthen regional sustainability in the interests of self-sufficiency, or even the well-known 'factor 10/factor 4' debate on the reduction of materials use (Hinterberger and Schmidt-Bleek 1999; Weizsäcker, Lovins and Lovins 1997). These suggestions all raised questions of feasibility, in view of historical realities.

All these aspects inspired our research interest, which goes far beyond historical curiosity, to really understand what 'agrarian society' and the agrarian socioecological regime is like in terms of both the biophysical features of society and its transformative impact on nature. This required a substantial effort in terms of data generation. While a large body of literature of course exists concerning the socioeconomic structure of agrarian societies (both in terms of social, economic and technological history and of cultural anthropology) and a rich body of agro-historical and agroecological work, our specific focus was to be the society–nature interface. To explore this, we needed comparable quantitative data on many cases differing in important respects. We wished to provide answers to the following general questions:

1. Is there a 'characteristic metabolic profile' of agrarian societies, in terms of energy and materials use? Can a general claim be made on the basis of what has been observed in some cases that the energy and materials throughput of agrarian societies is approximately factor 3–5 smaller than that of industrial societies? Is such a metabolic profile connected to and dependent upon certain land-use patterns that can be described on a general level? Or rather is every agrarian society a unique case, depending on its specific natural conditions and socioeconomic history?
2. What happens when this socioecological regime starts to change? What are the major drivers of such a change? What new options open up, and which new risks appear? Which pressures upon the environment gain momentum and which pressures recede? What changes in natural systems can be observed during the transition?
3. How much does the course of the agrarian–industrial transition depend on the historical (world) context? What difference does it make if a society is a worldwide pioneer of this transition (such as the United Kingdom), or is a comparative latecomer (such as the Austro-Hungarian Empire)? What, by comparison, does the transition look like when it takes place in a developing country, in a world context of a fully developed and dominant socioecological regime that is (post)industrial? Do common patterns exist with which all transitions comply, or must they be discussed on a strictly case-by-case basis?
4. How does the interplay between different spatial scales and levels of society work? As nation states undergo a transition from the agrarian to the industrial mode, their peripheral rural communities may hardly be touched upon – but in the course of the process, they come under great pressure to undergo change themselves. So how do these scales and levels interact?

Clearly, we are unable to answer such wide-ranging questions in any definitive way on the basis of a few cases within any one book. Nonetheless, we still hope that we have been able to make a serious contribution towards finding these answers by our decision to narrow down the range of phenomena we observed and to invest a great deal of methodological effort in creating a common protocol for their measurement. While the conceptual guidelines (as described in the previous paragraph) were fairly clear from the start, the specific operationalizations still presented a challenge. Responding to this challenge implied, for example, creating methods of material and energy flow analysis that allowed the generation and modelling of these data from historical records (something quite different from generating them, as is usual, on the basis of contemporary economic statistics). It also implied creating methods to describe historical land use in a way that would be comparable to modern, GIS-based procedures. Finally, it required creating a full methodology to analyse the biophysical features of local rural communities, with the help of observations, on-site measurement and interviews, which would generate a database conceptually comparable to existing ones on the national level.

Somewhat more in the mainstream of material and energy flow analysis, but still a major methodological achievement, was the generation of MEFA databases for several developing countries that did not yet have any experience in this, and that had hardly any adequate economic statistics: this involved organizing extensive training for local experts, and supervising their work for extended time periods.[21] Thus, while the focus of this book is not primarily methodological, substantial parts of several chapters are devoted to explaining and discussing methodological issues.

As explained above, we have taken a comparative approach in attempting to find answers towards our 'grand' questions. We compare social systems, described according to their biophysical features, in transition from an agrarian to an industrial socioecological regime. This is performed in one of two ways: either long time series of observations exist across the period where the transition takes place (as in Chapters 2 to 4 and partially in Chapter 5), or we know from sources external to our primary research that we are dealing with societies in transition and may describe and/or compare their features at one specific point in time (as in Chapters 6 and 7 and some parts of Chapter 5). We treat each of the cases we have included in comparative analysis as a complex system with various strongly interdependent features. So although we have gathered and present quantitative data, we rarely compare results on single dimensions but try instead to take into account the complex mechanisms interlinking these data. This approach creates some difficulties in terms of presentation and we have yet to invent a standard procedure for this endeavour. Thus the reader will find that each chapter seeks its own way to respond to this challenge. Furthermore, the cases presented are not only complex cases in their own right, but they are ordered on different sides of important distinctions (see Figure 1.4).

While each case in itself represents a transition from the agrarian to the industrial socioecological regime, it may be characterized according to its position on two relevant axes. One axis refers to spatial scale (or level of organization) and distinguishes between local and national cases. Chapter 5 is particularly devoted to this issue, as it compares the long historical time

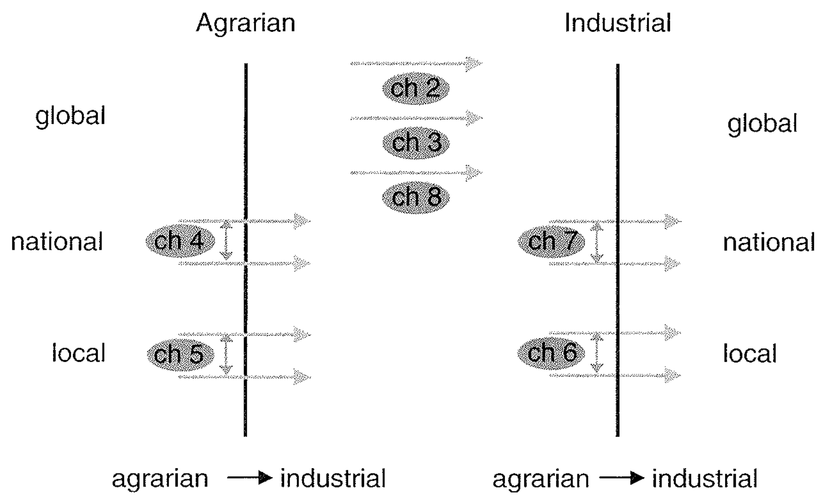


Figure 1.4 The role of the book chapters in exemplifying relevant distinctions

series data on the national level discussed in Chapter 2 with data on various local communities between the years 1830 and 2000. This chapter is intended to make a specific contribution to the question of how different levels in transitions interrelate. Other chapters (such as Chapters 6 and 7) also contribute to issues of spatial scale, although their main focus is different.

The other axis characterizes the world context. During the whole time period we are dealing with (from about 1600 to 2000) the 'great transformation' takes place, and in Chapters 2 and 3 we try to capture the overall process. While Chapter 2 attempts a grand view as to what this transformation implies in terms of socioecological regime change, Chapter 3 deals with some important implications of this for global environmental change, in particular with the impacts upon the carbon cycle. As this transformation goes on and gradually spreads (both regionally and in depth), the context for 'newcomers' changes. It should make a significant difference whether a country's transition from the agrarian to the industrial socioecological regime occurs as a pioneer case, or if it can make use of technologies and organizational experiences from elsewhere, but also has to reach an accommodation with the established economic power structures created and dominated by forerunners. This question is dealt with for specific cases in Chapters 5, 6 and 7, while Chapter 8 then systematically compares the paths to industrialization of the (pioneering) United Kingdom and the (latecoming) Austro-Hungarian Monarchy, and contrasts them with ongoing changes in contemporary developing countries. There exist several other relevant differences between those former empires, of course, such as access to overseas colonies or the transport and trade conditions of an island versus a geographical location in alpine regions of a large continent, and each developing country's history again makes for a particular case that we represent only insufficiently in this book. As such, our explanations are bound to be far from exhaustive; the interesting question, however, is whether we can establish similarities across those differences, that may legitimately be attributed to the respective socioecological regime.

Chapters 6 and 7 deal with social systems that are still in transition from the agrarian to the industrial regime themselves, but in a world context that is already completely dominated by the industrial socioecological regime. They all fall under the label of 'developing countries' yet are highly differentiated among each other, ranging from Brazil to some of the poorest countries of the world such as Laos. For the local case studies in Chapter 6, it is hard to tell in what way this world context matters but the chapter's analysis addresses the question of what difference the national (usually also transitional) context makes. The comparisons in Chapter 7, on the other hand, deal with the national scale and draw their main explanatory power from relating this to the global context and analysing the specific role a country occupies within an international division of labour as a determinant of transitional pathways.

Finally, Chapter 8 seeks to knit together those strands of insight generated by the previous chapters towards formulating preliminary answers to our major questions. It also critically reviews the premises of the whole enterprise: whether it makes sense to use the sociometabolic transition from the agrarian to the industrial regime as a key to unlocking better understanding of possible transitions towards sustainability.

The central theme underlying this book is the notion that most, if not all, global sustainability issues have to do with the fact that about two-thirds, if not three-quarters of the world population are currently in the midst of a rapid transition from agrarian society to the industrial regime. This transition is fundamentally changing societal organization, economic structures, patterns of resource use and so on, thereby probing the limitations of the planet Earth in many ways, among others by using up exhaustible resources, altering global biogeochemical cycles, depleting biological diversity and degrading the Earth's ecosystems (Millennium Ecosystem Assessment 2005). All of this is triggering a process of global environmental change comparable to past transitions in the Earth system such as those between Ice Ages and warm interglacial periods (Schellnhuber et al. 2004; Steffen et al. 2004). What seems clear is that neither the Earth's mineral resources, nor the adaptive capacity of the biosphere will suffice to allow the transition of six or even nine billion people (Lutz et al. 2004) to the current pattern of industrial resource use: humanity's use of natural resources already exceeds the regenerative capacity of the biosphere by at least 20 per cent (Wackernagel et al. 2002).

We are sceptical about the notion that a clearcut set of measures could be identified here and now that would bring about a transition towards sustainability. Rather we subscribe to the view that a better understanding of this transition process may help us to identify ways to intervene in ongoing transitions in a useful way. Overall, this book is intended to contribute to this analytic endeavour.

NOTES

1. During this period, water use and pig population, for example, increased ninefold, the world economy 14-fold, energy consumption and CO^2 emissions 17-fold, world trade 22-fold, marine fish catch 35-fold, industrial output 40-fold and, finally, world freight transport by a factor of 135 (McNeill 2000).
2. In mathematical terms, growth or modernization processes can be adequately described by correlations and econometric models, whereas for transition processes different models are required that can capture the discontinuity of interrelations (Ayres 2000).

3. At least in principle, this competition could be resolved mathematically by finding the model, or the group of models, with a better fit. It is nonetheless more interesting to compare the intellectual service each of the theories provides.
4. There is an obvious similarity between the 'stabilization' phase and the highly connected, stable phase and between the 'pioneer'-dominated third transient phase and the 'acceleration' phase. Whether or not it is helpful for the analysis of socioecological systems to break up the 'take-off' phase in two phases, one of release and one of reorganization, may depend on the circumstances.
5. For a careful analysis of types of evolutionary theories in biology and the social sciences see Weisz (2002).
6. See also the book series *Routledge Studies of Societies in Transition*.
7. It is interesting to note that in the *Communist Manifesto* (Marx and Engels [1847] 1998) the advent of socialism appears as inevitable as the advent of capitalism before it. In his later writings, Marx became more cautious about imputing such mechanics to history.
8. Analytically, these approaches owe much to the research tradition on patterns of technological change in the past, such as Grübler (1994); Nakicenovic (1990); Perez (1983).
9. Such as a common language, a system of legislation, a currency and a certain minimum of shared everyday customs and habits.
10. As in the textbook definition by Harris, according to which society is an 'organized group of people who share a habitat and who depend on each other for their survival and well-being'. 'Each society has an overall culture', he adds, which, however, need not be uniform for all members (Harris 1987, p. 10).
11. Luhmann has spent more than two decades developing his theory in a very thorough and consistent way (Luhmann 1984; 1997). As a social scientist, it is very helpful to be able to draw on such a well-integrated body of groundwork. English translations of some of Luhmann's major works have only recently become available (see, for example, Luhmann 1995).
12. The terminology is close to Rolf Peter Sieferle's way of looking at culture (Sieferle 1997a), but rather far from the traditions of cultural anthropology and of most sociological writers.
13. The term 'hybrid' as a scientific term originates from biology, where it refers to the 'offspring of a cross between two different strains, varieties, races, or species' (Walker 1989). Within the social sciences, the French science critic Bruno Latour (1998) in particular made this term central to his theoretical approach. According to Latour, hybrids signify human creations that, inseparably, are both creatures of culture and creatures of nature. Latour argues that pre-modern thinking had assumed a certain unity of the social and the natural, the human and the non-human, nature and culture, the subject and the object. The idea of separating nature and society belongs to the very constitution of modernity (Latour 1998, p. 22). But while modern thinking, modern science, strips its natural objects of all communicative capacity and political relevance on the one hand and frees society of natural (or transcendent) determination on the other, this results in continuously creating mixed creatures (hybrids, sometimes also called 'monsters') that exert a powerful influence upon the destinies of both society and nature. The unconsciousness with which this is performed, the lack of conceptual tools to deal with these hybrids and the built-in ambiguity of the distinctions, on one hand makes modern thinking invincible (p. 53) while on the other it fills the world with potentially dangerous 'quasi-objects'.
14. This concept is, to some extent, similar to that proposed by Schellnhuber to define the Earth system as consisting of two main components, N and H, where N (the natural system) is assumed to consist of components such as the atmosphere, the biosphere, the cryosphere and so on, and H (denoted by Schellnhuber as 'the human factor') consists of the so-called 'physical subcomponent' or 'anthroposphere' (in the words of Schellnhuber 1999 [C20]: 'the aggregate of all human lives, actions and products') and a 'metaphysical' sub-component roughly comparable to the notion of 'culture' as employed in Figure 1.1 of this chapter. However, Schellnhuber's concept lacks an understanding of human

society – both in its physical and its 'metaphysical', or cultural aspects – as a complex autopoietic system.

15. Foster (2000) makes a very convincing attempt to demonstrate that Marx was indeed aware of the ecological consequences of changing means of production and that he did see natural conditions as changing and thereby influencing society. However, this line of Marx's thinking seems to have been almost entirely restricted to agriculture and did not shape his overall model of historical transitions.
16. See Goudsblom's 'principle of paired increases in control and dependency' (Goudsblom, Jones and Mennell 1996, p. 25).
17. They already differ from all other mammals, however, through the utilization of fire. Burning wood is a method of transcending contemporaneous energy flows by mobilizing stocks; on the other hand, controlled burning of dry vegetation alters the landcover and makes regions more accessible for hunting (Goudsblom 1992).
18. Current research into the global carbon cycle – an important aspect of earth system analysis – still proceeds exactly in this way (for example, Houghton 1995; Houghton and Skole 1990).
19. It may appear unusual to call the economy a 'cultural system'. To justify this definition, we argue as follows. Our point of departure is the distinction between a 'natural' and a 'cultural' sphere of causation (see Figure 1.1). If we follow Luhmann's specification of subsystems of society, the economy deals in the medium of money, a symbolic device representing value. While classical 'political economy' theorists (Smith, Ricardo, Marx) still formulated their theories in a 'hybrid' fashion, referring equally to physical and monetary units, 20th-century economics increasingly liberated itself from a physical reference. This change seems not to have taken place only on the level of scientific discourse, but also on the level of the corresponding 'reality', where financial phenomena are increasingly decoupled from any physical process.
20. The primary empirical material of these case studies was generated by projects financed by the European Commission (especially the FP5-Incodev programme), the statistical office of the European Union, Eurostat, the Austrian Federal Ministry of Science's social science programmes (Nicobars: Indian and Cultural Studies), the Breuninger Foundation and the Austrian National Science Fund. Crucial funding came from the Austrian Ministry of Science's research programme on 'Cultural Landscapes' – this funding allowed us to go beyond single case studies and engage in comparative analysis.
21. Our philosophy, in accordance with the respective EU-financed research programme, was not just to generate data on developing countries but to stimulate the growth of a local capacity to do so in terms of fostering expertise. At the same time, we conceived incentives for them to look comparatively at each other and learn from each other, and not to fix their attention upon us and the other European research teams involved. In selected cases, our efforts in capacity building went as far as inviting collaborating researchers to undertake their PhD research in Vienna and then return as senior scientists to their countries. We thank IHDP-IT for supporting this with recommendations for European START scholarships, as well as the ASEAN bank for its help. We also thank IHDP-IT for endorsing, and sometimes supporting financially, regional workshops (such as those in Manaus in 2001, in Ho Chi Minh city in 2002 and in Rio de Janeiro in 2003).

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