Chapter 2 Out of control?

Complex adaptive systems of humanity and its environment

Peter Bodo[1], Robert Nemeskeri[2], Marton Herczeg[3], Oksana Mont[2]

[1]Geologika (peter.bodo@geologika.hu); [2]IIIEE, Lund University,
[3]Danish Topic Centre on Resources and Waste Management

1 Introduction

Physical and biological systems, human mind, culture, market and some types of technology have been successfully modelled as co-evolving complex adaptive systems. The authors present a general framework for studying this co-evolution, investigate the opportunities for control, and provide recommendations for intervention. Regulation is also co-evolving with, thus adapting to the other systems, necessarily limiting its possibilities, what an accurate model for policy intervention has to consider. While direct control on complex adaptive systems is hardly possible, there are ways to influence the system to increase the possibility of more sustainable trends. Since economy is coevolving with other human and non-human systems, the necessary leverage points are not restricted to the economic system. The authors provide evidence that sustainability is not compatible with its current definition involving the goal to fulfil needs, therefore a paradigm shift is necessary. Needs, based on genetic and cultural motives, are also evolving, and the effort to fulfil them creates a reinforcing drift in the co-evolution with other socioeconomic systems.

2 Complex adaptive systems

Complexity theory has been coined by Santa Fe Institute researchers in the beginning of the 1990s. They have defined a system as complex in the sense that a great many independent agents are interacting in a great many independent ways. The very richness of these interactions allows the system as a whole to undergo spontaneous self-organisation (Waldrop, 1992).

The properties of the whole system can be completely distinct from the properties of the interacting agents, i.e. the system has new, emergent properties. A classic example is the bird flock, where, in the absence of a leader, the birds follow very simple rules in relation to their closest neighbours, the group as a whole carries out a coordinated movement. Another example is that in any city in a developed country there are always

Proceedings: Sustainable Consumption and Production: Framework for action, 10-11 March 2008, Brussels, Belgium.Conference of the Sustainable Consumption Research Exchange (SCORE!) Network, supported by the EU's 6th Framework Programme.

nearly two weeks of food supply without any common strategy that would manage and control food supply. Emergence and feed-back processes continuously create and organise the system.

It is important to note that complex adaptive systems can be nested, e.g. the market is a complex adaptive system made up of a huge number of selling and buying agents, but also a company (or any organisation) is a complex adaptive system. It is also notable that the relationship between the agents is generally far more important than the agents themselves, because the emergent patterns are formed from these connections.

Research is indicating that CASs have a number of characteristics (Chan, 2001):

- Distributed control
- Connectivity
- Co-evolution
- Sensitive dependence on initial conditions
- Emergent order
- Far from equilibrium

As Darwin (1859) has first described natural selection, and others (Dobzhansky, 1937; Mayr, 1942; Simpsons, 1944; Hamilton, 1964; Axelrod and Hamilton, 1981; Dawkins, 1989) have developed it further, we can describe evolution with three sufficient and necessary criteria:

- reproduction
- variation
- selection

A common misinterpretation of evolution is to imagine it as one life form's adaptation to a stable environmental niche. In fact, all other life forms are adapting to their own environment and what's happening is the co-evolution of all life forms, all having a changing environment. The co-evolution of system and environment is visualised by Figure 1. The interacting links are not deterministic, but can be described by Markov-steps (stochastic matrices).

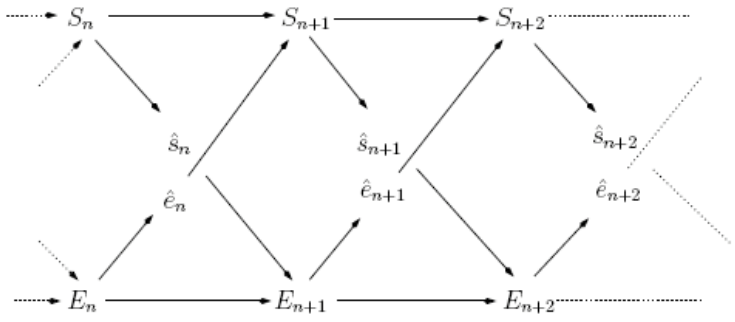

Figure 1: Co-evolution. The system (S) and the environment (E) interact through the channels of ŝ and ê. The figure shows the temporal dependencies of this interaction (Source: Bertschinger et al., 2007)

The systems of needs, culture, market, regulation, ecosystems, and physical environment have been identified as complex adaptive systems by matching the attributes of CAS and the conditions of co-evolution with the respective system properties. Thus a model has been created summarising the long-term co-evolution of these systems and implication on potential interventions for more sustainable production and consumption levels.

3 Coevolving social, economic and environmental systems

3.1 A system view on actors and needs

As the many approaches to characterise needs and actor's behaviour in the socioeconomic context has made it evident, humans needs and actions are the result of many underlying factors. Therefore a direct causality cannot be set up on the basis of human actions. The motives and potentials of human actions are resulting from the respective culture, technology, regulatory framework, personal history, economic status, fulfilled social roles, etc. While it is hard to set up causality at the micro-level among the various behaviours, it is possible to study the causality of macro-systems. There is a wide range of literature dealing with how culture affects technology or institutions, including market types, how human genes and human environment influences cultural evolution, and a handful of literature also deals with how and how much regulation is able to change market and technological evolution.

Consequently, instead of analysing in detail the micro-level potential to change behaviour, the paper focuses on the establishment of an evidence base on how the various environmental and human macrostructures – which form human behaviour – are related to each other. Therefore in the following subchapters a general framework is presented, where the physical environment, the ecosystem, culture, regulation, market and technology are tested against the criteria or attributes of complex adaptive systems and examples are provided how these systems affect each others long-term evolution.

Thus, instead of recommending policy intervention to change actor's behaviour, the project recommends intervention to influence the evolution of various macro-systems in a way that it will change actor's behaviour favourably. The underlying idea is that human behaviour is largely limited by environmental, cultural, regulatory, technological, and market factors, while the evolution of these factors is out of direct control. The most policy makers are able to do is to attempt to influence the evolution of these factors in a way that more "sustainable" behaviour becomes possible and desirable for individual actors.

3.2 An early co-evolutionary framework of social change

Norgaard (1994) has introduced a co-evolutionary framework with five co-evolving systems: values, knowledge, organisation, environment and technology. In Figure 2 the framework is visualised as each system is co-

evolving with all other systems. While this framework is intuitive and elegant and provides useful assistance in analysing social phenomena, the selection of the various systems for the framework is not self-explanatory.

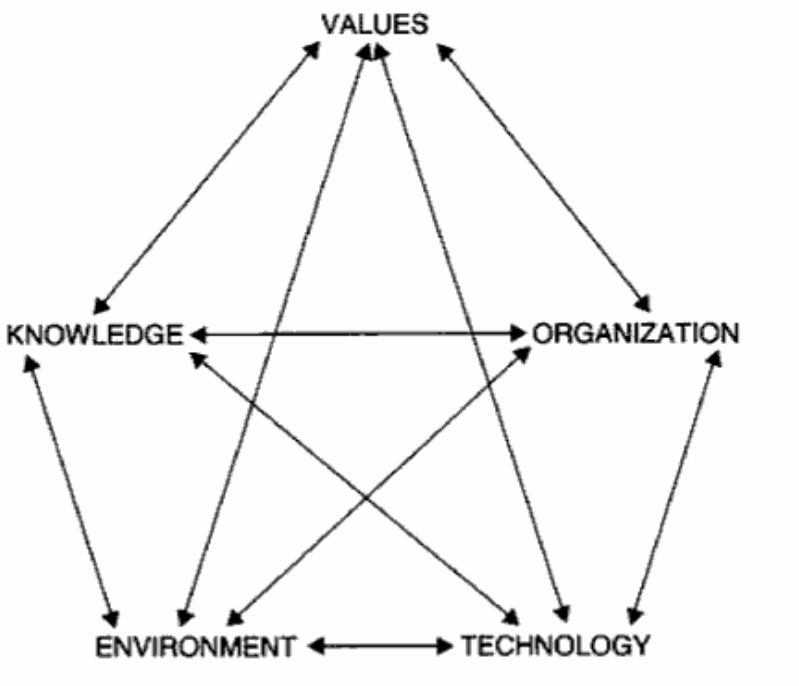

Figure 2: The co-evolutionary process as described by Norgaard, 1994

In the following subchapters, the authors identify those interconnected human and environmental systems, where co-evolutionary processes have been identified by the different disciplines and thus an improved co-evolutionary framework can be created. The following disciplines have been applied:

- Psychology (esp. evolutionary);
- Sociology and anthropology;
- Economics (neoclassical, environmental, ecological, evolutionary, institutional, etc.);
- Biology; and
- Physics.

3.3 Human needs

Since needs are the central elements of defining sustainability, their role in the sustainability debate is cardinal. Meanwhile, defining needs is a major weakness, which creates a large confusion about the goals and tools to realise more sustainable production and consumption patterns.

According to the authors the prime source of hardship in defining needs is confusion of descriptive and normative terms in the definition. When needs are defined as a fundamental basis of human rights, what everyone

should be able to fulfil, it is a normative definition. Since norms are culturally defined, a normative definition of needs is characteristic to the certain cultures. With changing cultures and cultural values the normative definition of needs are also changing as we have experienced for example through hygiene becoming a basic need in the last one or two centuries. There is a mix of descriptive and normative definition when basic needs are attempted to be described. These are often described as sustenance conditions and upon the recognition that those alone should not be fair other elements of human rights are added. However, it is possible to define needs descriptively as the motives of human behaviour. Evolutionary psychology describes needs as functional mental mechanisms to motivate adaptive behaviour. These are partly genetically evolved and partly culturally adapted.

3.3.1 Genetic needs

> "Plato says . . . that our ''necessary ideas'' arise from the preexistence of the soul, are not derivable from experience — read monkeys for preexistence."
>
> Charles Darwin, M Notebooks (entry 128)

Our genetic "needs" are evolutionary adaptations and their function is to motivate humans for adaptive behaviour, which increase the chance of genetic survival (inclusive fitness). Being hungry or thirsty, feeling disgust in closeness of faeces, fear in closeness of something threatening security are the simple examples, but there is evidence that there are a very huge set of computational procedures motivating humans to very specific behaviours.

> "Distinct and incommensurable evolved motivational principles exist for food, sexual attraction, parenting, kinship, incest avoidance, coalitions, disease avoidance, friendship, predators, provocations, snakes, spiders, habitats, safety, competitors, being observed, behaviour when sick, certain categories of moral transgression, and scores of other entities, conditions, acts, and relationships. Not only is there an irreducible number of domains, but there is an irreducible set of domain-specific criteria or value-assigning procedures operating within each domain e.g., for food: salt, sweet, bitter, sour, savoury, fat affordances, putrefying smell avoidance, previous history with the aversion acquisition system, temporal tracking of health consequences by immune system, stage of pregnancy, boundaries on entities and properties considered by the system, perhaps maggot-ridden food avoidance, and scores of other factors" (Tooby et al., 2005).

Furthermore there is evidence that humans have special computational mechanisms in support of social exchange. It has been proved that there is a kin detection algorithm to support kinship-based altruism (and also to inhibit sexual desire towards kins) (Lieberman et al., 2007); there is a cheater detection algorithm to facilitate reciprocal altruism; also there is a motive to punish cheater, functionally specialized for removing the fitness advantage enjoyed by free riders rather than for labour recruitment or other functions. Results also support the hypothesis that a separate pro-reward motivational system exists that appears designed to handle the problem of labour

recruitment (Price et al., 2002). Since genetic formation of complex adaptations need 1,000-10,000 generations or 20 to 200 thousand years, genetic needs are universal and in our timescales stable.

According to Bernard et al. (2005) genetic needs are to guide behaviours and interests within one of five social domains related to ever larger systems:

- the self-protection domain of the single system;
- the mating domain of the dyadic system;
- the relationship maintenance and parental care domain of the small, kin system;
- the coalition domain of the large, non-kin system; and
- the "memetic" domain of the large, symbolic, cultural system.

> "All motives, old or recent, are hypothesized to express as phenotypes in a historical and presently recurring interaction between genotype and the physical–social–cultural environment. Emotions are hypothesized to guide purposeful behaviour toward inclusive fitness goals by assisting "if–then" searches among motives. Self-control is hypothesized to delay behaviour, permitting more thorough if–then emotion-referenced searches and increasing the probability that behavioural responses are adaptive in the local environment." (Bernard et al., 2005)

3.3.2 Culture

> "There was once a man who lived in a Scarcity. After many adventures and the long voyage in the Science of Economics, he encountered the Society of Affluence. They were married and had many needs."
>
> Baudrillard 1988, p. 35.

Culture is group-specific collection of shared traditions of values, beliefs and artefacts; or else problem-solving methods. Note, that some animals also have the ability for culture. E.g. chimpanzees have cultures of more than 30 traditions, which differentiate distinct groups. Field research and experiments have proved the existence of cultures and the ability to teach and learn cultures among chimpanzees (Whiten et al., 2007). The adaptive importance of culture has been the very quick evolution of problem solving. While genetic adaptation needs 1,000-10,000 generations, cultural evolution made possible adaptive changes within just generations.

As genetic needs are prime motivators, culture is rooted in genetic needs; though, cultural elements might overwrite unconscious needs as motivators (e.g. celibacy, suicidal terrorism, etc.), since group identity is one of the important human needs and culture is one of the major signifiers of group identity. When culture strengthens the genetic motives of pleasure seeking culture is hedonist, when culture replaces or denying the fulfilment of some of the genetic needs culture is ideologist. Culture is very much formed by the groups history and thus by the environment the group is living in. Environmental determinists emphasise this impact of the environment on culture, while genetic or biological determinists emphasise the role of

genetic motives on the formation of culture. Most likely is that most of the human culture is highly determined by our genetic programmes, however, the obvious differences are determined by the different history and thus partly the different environment of various groups. Certainly the cultural differences are easier to recognise than the globally shared part of culture. Thus while environmental psychology discusses in detail what are the genetic bases of the emergence of culture (Tooby and Cosmides, 1992), anthropologists and sociologists rather concentrated on the cultural differences caused by – among others – environmental and climatic factors (Hofstede, 2001; Van de Vliert, 2007). Abel (1998) have listed the following as examples for emergence in cultural evolution:

- The emergence of food production technologies and domestication.
- The emergence of labour specialisation.
- The emergence of private property.
- The emergence of large, permanent human social groups.
- The emergence of social inequality, related to the asymmetrical control of the productive resources and technologies by factions within a society.
- The emergence of organized warfare and specialized coercive military/police institutions.
- The emergence of markets and the expansion of trade.
- The emergence of political chiefs and chiefly lineages.
- The emergence of institutionalized religion and religious specialists.
- The emergence of irrigation agriculture.
- The emergence of legal/financial/monetary technologies.
- The emergence of state bureaucracy.
- The emergence of modern world systems, and supranational legal/financial institutions.

On the micro-level, cultural elements are becoming parts of our Selves. We are inclined to believe that we have a stable core in our mind, and while our emotions, feeling, thoughts and behaviour can be shaped by our learnt culture and genetic programmes, this stable core remains in control and able to make free decisions. Contrary, modern psychology cannot define anything, which could be regarded as a self separated from our subconscious and conscious perceptions and motives (e.g. Csikszentmihalyi, 1993). Instead their definition of the Self is an evolving system of genetic and cultural programmes, which intends to remain consistent. The idea is also supported by social scientists who define social identity as a collection of traits. Marcia (1966) argues that a person's freedom to change his/her identity is through choice and commitment, however within this exercise self-consistency remains strong motive.

However, as Bowles (1998) concludes just as the process of natural selection does not generally maximize average fitness, there is no reason to expect that the process of cultural transmission determining the equilibrium distribution of traits in the population will support a socially optimal outcome. The cultural equivalent of a market failure thus results; indeed the long-term persistence of socially and even individually disadvantageous norms is hardly open for questioning.

According to Shove (2003) much of the extremely environmentally costly consumption is related to ordinary, routinised and taken-for-granted practices, and it is therefore important to study how these normal practices are constructed and develop over time. The perspective is formulated in opposition to the approach taken in much research on sustainable consumption where the relationship between individual "green" beliefs and individual behaviour is studied. Shove argues that studies on individual "green" behaviour tend to deal only with the tip of the iceberg—a minor part of the environmental impact related to consumption. The major part relates to the long-term changes of daily life and the changing collective conventions regarding the constituents of a normal life.

Shove and Warde (1998) has identified five mechanisms supporting the escalating levels of consumption. These mechanisms are based on cultural motives, most deeply rooted in human genetic motives:

- social comparison;
- the creation of self-identity;
- mental stimulation and novelty;
- aesthetic matching; and
- specialisation within daily life.

Culture has shaped the social and physical environment through institutions and technology. While market and regulatory institutions are also part of culture, their evolution has become distinct from cultural evolution. Normally cultural elements are competing for human attention (a very scarce resource) and if they proved to be adaptive enough and consistent with the existing Self they are integrated in the Self. With the creation of an artificial resource (financial capital), the level of human attention required has been considerably decreased and market procedures (through the application by market actors) are able to compete on different ground. Thus market has become a distinctly evolving complex adaptive system. Regulation went through a similar process, as political parties and political programmes competing for majority votes have significantly decreased the level of human attention required for creating norms. Nevertheless, regulation is more deeply rooted in the system of cultural values in the democratic decision-making process.

3.4 Market and regulation

The evolution of markets has been addressed by many researchers of various disciplines (e.g. Teilhard de Chardin, 1959; Hayek, 1967; Matthews, 1984; Dawkins, 1986; Arthur, 1989 and 1994; Michaelis, 1997; Ormerod, 2001; Mauboussin, 2002). Meanwhile market evolution also changes its evolutionary environment, i.e. culture, regulation, technology and certainly the physical environment and the ecosystem. Bowles (1998) emphasises that markets influence values, tastes and personalities. As he puts it:

> "The production and distribution of goods and services in any society is organized by a set of rules, among which are allocation by fiat in states, firms, and other organizations, patriarchal and other customary allocations based on gender, age, and kinship (as for example takes place within families), gift, theft, bargaining, and of course markets. Particular combinations of these rules give entire societies modifiers such as

> 'capitalist', 'traditional', 'communist', 'patriarchal', and 'corporatist'. These distinct allocation rules along with other institutions dictate what one must do or be to acquire one's livelihood. In so doing they impose characteristic patterns of interaction on the people who snake up a society, affecting who meets whom, on what terms, to perform which tasks, and with what expectation of rewards. One risks banality, not controversy, in suggesting that these allocation rules therefore influence the process of human development, affecting personality, habits, tastes, identities, and values. One cannot be too far out on a limb when in the company of Adam Smith as well as Edmund Burke, Alexis de Tocqueville and Karl Marx, John Stuart Mill and Frederick Hayek: all celebrated or lamented the effects of markets and other economic institutions on human development."

Bowles (1998) has identified five important mechanisms through which market influences preferences:

- *Framing and situation construal*: economic institutions are situations in the social psychological sense and thus have framing and other situation construal effects; people make different choices depending on whether the identical feasible set they face is generated by a market-like process or not.
- *Intrinsic and extrinsic motivations*: the ample scope of market choices and often extrinsic nature of market rewards may induce preference changes driven by individual desires for feelings of competence and self-determination; other institutions may have related effects.
- *Effects on the evolution of norms*: economic institutions influence the structure of social interactions and thus affect the evolution of norms by altering the returns to relationship-specific investments such as reputation-building, affecting the kinds of sanctions that may be applied in interactions, and changing the likelihood of interaction for different types of people.
- *Task performance effects*: economic institutions structure the tasks people face and hence influence not only their capacities but their values and psychological functioning as well.
- *Effects of the process of cultural transmission*: in part for the above reasons, and in part independently, markets and other institutions affect the cultural learning process itself, altering the ways we acquire our values and desires, including child rearing and schooling, as well as informal learning rules such as conformism.

Others providing examples and proof on endogenous preferences include van den Bergh et al., 2000; Rodríguez-Sickert et al., 2007; Gneezy and Rustichini, 2000; and Falk and Kosfeld, 2004. Bowles' (1998) conclusion is that because states, communities, and markets may influence the process of cultural evolution, any normative evaluation of the role and scope of these institutions must attempt to take their cultural effects into account. Such an attempt has been carried out by Putnam (2000) who found that the decline of social capital in the United States in the last couple of decades has been caused by:

- economic changes (social "pressure" of business and time);

- caused changes in family models;
- spatial mobilisation and suburbanisation;
- technological changes; and
- changes in society and social politics.

Or as Soros (1997) recognises "society has lost its anchor", by the market shaping our cultures and cultural values::

> "Instability extends well beyond financial markets: it affects the values that guide people in their actions. Economic theory takes values as given. At the time economic theory was born, in the age of Adam Smith, David Ricardo, and Alfred Marshall, this was a reasonable assumption, because people did, in fact, have firmly established values. Adam Smith himself combined a moral philosophy with his economic theory. Beneath the individual preferences that found expression in market behavior, people were guided by a set of moral principles that found expression in behavior outside the scope of the market mechanism. Deeply rooted in tradition, religion, and culture, these principles were not necessarily rational in the sense of representing conscious choices among available alternatives. Indeed, they often could not hold their own when alternatives became available. Market values served to undermine traditional values.
>
> There has been an ongoing conflict between market values and other, more traditional value systems, which has aroused strong passions and antagonisms. As the market mechanism has extended its sway, the fiction that people act on the basis of a given set of nonmarket values has become progressively more difficult to maintain. Advertising, marketing, even packaging, aim at shaping people's preferences rather than, as laissez-faire theory holds, merely responding to them. Unsure of what they stand for, people increasingly rely on money as the criterion of value. What is more expensive is considered better. The value of a work of art can be judged by the price it fetches. People deserve respect and admiration because they are rich. What used to be a medium of exchange has usurped the place of fundamental values, reversing the relationship postulated by economic theory. What used to be professions have turned into businesses. The cult of success has replaced a belief in principles. Society has lost its anchor."

Regulation cannot be blamed directly on market failures and related cultural effects, since regulation itself is formed by the evolution of the various macro systems. According to Sotarauta and Srinivas (2005) the relationship between policy and development is reciprocal even though it is often seen as, or hoped to be, a linear process proceeding from planning to decision to implementation to changes in development.

3.5 The physical environment and the ecosystem

Ecosystems are the prototypical examples of complex adaptive systems (e.g. Levin, 1998; Norberg, 2004). In the ecosystem patterns at higher level emerge form localised interactions and selection processes at lower levels.

Various life-forms are co-evolving with other life forms and reliable and rapid feedback mechanisms ensure the essentials for a tight co-evolution (Ehrlich and Raven, 1964; Futuyma and Slatkin, 1983; and Levin, 1983).

Many domains of the physical environment are adapting quickly to the changed conditions by the ecosystem. Changing composition of the atmosphere, changing patterns of hydrological cycles, as well as soil formation are examples for the co-evolution of the ecosystem and the physical environment. This matching of life and the conditions for life has inspired views of the earth as a superorganism (Hutton, 1788), with a biota and an atmosphere that have coevolved (Lovelock, 1972; Margulis and Lovelock, 1974). Without accepting or denying the Gaia hypothesis (e.g. Lenton and van Oijen, 2002), it is possible to recognise the attributes of complex adaptive systems and co-evolution among the elements of the physical environment and the ecosystem.

3.6 Technology

Technology is defined here as a species' adaptive change of the environment. As such, a bird nest is a technology created by birds to change their environment in order to improve their evolutionary conditions. Human technology today is very much different of the bird nest, since it is overwhelmingly culturally driven. The development of technology can be regarded as a complex adaptive system since it is fully integrated in cultural evolution. Nevertheless, manifest technology in most cases cannot be regarded a complex adaptive system, since it lacks the ability to adapt once created. The key to resilience in any complex adaptive system is in the maintenance of heterogeneity, the essential variation that enables adaptation (Levin et al., 1998). However, as Levin (1998) puts it:

> "Heavily managed systems, such as in agriculture or forestry, are not purely complex adaptive systems, in that their simplified structures are imposed exogenously rather than arising endogenously. As such, they are fragile, vulnerable to single stresses such as pest outbreaks that cause system crashes in the absence of adaptive responses."

This is true to other technology forms as well. Since in most cases technology is not an adaptive system, co-evolving with its environment, in most cases technology starts deteriorating as soon as it is created. There are few examples in ancient traditional technological domains (such as agriculture) where people have been able to accumulate extended knowledge on how their technology interacts with the environment. Traditional agricultural practices of diversifying crops, providing time for soil remediation and similar practices are elements to improve the adaptation of technology; however, an active exogenous reinforcement is still necessary to sustain it. Permaculture is an attempt to create a truly adaptive and resilient agricultural system (Mollison and Holmgren, 1978). Another adaptive technology emerging recently is the Internet, where the evolution is out of (an exogenously or from the above imposed) control and the emergent phenomena are the result of numerous interactions on the lower level. Other potential fields for adaptive technologies are nanotechnology and biotechnology, including the threats such adaptive systems could potentially pose on humanity.

Though it has been stated that technology in its physical reality is normally not a complex adaptive system, the knowledge on which humanity develops its technology, as part of culture, is a complex adaptive system. Innovation, the creation of new types of technology, is very much stimulated by our current economic system. The adaptive nature of market evolution has been described long ago, e.g. by Schumpeter (1943):

> "But in capitalist reality as distinguished from its textbook picture, it is not that kind of competition that counts but the competition from the new commodity, the new technology, the new source of supply, the new type of organization (…) - competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives."

Innovation in technology for a market entity is very similar in its goal to any kind of innovation adaptive systems carry out, the goal to avoid competition. For market entities the goal for innovation is to create temporary monopoly situations. Certainly, this results in a new sort of competition in the speed of innovation. Those who are the fastest innovators have the chance for market success. However, on the macro scale faster and faster innovation has its drawbacks. As Arthur (1994) describes it:

> "If exploitation outweighs exploration, learning may converge too rapidly on promising-looking actions. What is crucial then to the emergence of the optimal action is a slowing down of the speed of convergence, so that learning has time to explore less promising alternatives. The data – not the algorithm – show that in human learning such slowing down does not occur. I would therefore expect the result that human learning is path-dependent, nonpredictable and not necessarily optimal to be validated […]"

3.7 Human and environmental systems in a co-evolutionary framework

Table 1 and Table 2 below matches the various attributes of a complex adaptive system (system elements, relationships among the elements, emergent properties) with the different human and environmental systems described in the previous sections. Furthermore the specific systems' environments are identified and the processes of the system-environment co-evolution are summarised.

Table 1: Attributes of complex adaptive systems in human systems

	System of needs	Culture	Market	Regulation
System elements	Genetically inherited computational mechanisms and culturally transmitted knowledge	Units of shared knowledge in individuals' mind	Market practices and procedures	Pieces of legislation
Relationships	Prioritising mechanism (using emotions and memory)	Competing and strengthening each other to create a consistent Self	Competing market procedure for increased returns on investment	Competing and strengthening each other to create a consistent legislation
Emergent property	Self (and adaptive behaviour at the micro-level)	Culture (and adaptive behaviour at the macro-level)	Economic system (web of supply chains, strategic alliances, imitators, etc.)	Legislation (system of norms to optimise society)
Environment	Physical environment, ecosystem, social environment, potential mate, own body	The subconscious mind (incl. genetic needs), the social and physical environment	"STEEPLED" (political, economic, socio-cultural and technological environment as well as environmental, legal, education and demographic environment)	Cultural values (voter preferences) Economic "realities" Technological possibilities
Co-evolution: Environment to system	Needs evolved towards human, social, natural, and infrastructural capitals	Human specific genetic and groups specific environmental influences on culture	Genetic and cultural motives determining preferences STEEPLED determining opportunities	Political programmes are selected by and adapted to voter preferences
Co-evolution: System to environment	Maintaining healthy body, social relationships, consuming resources from the environment	Social environment: (market and regulatory) institutions Physical environment: technology	Market institutions changing values Market induced technology changing physical environment Market induced technology changing culture	Regulation become norms and cultural values with time Market and technological evolution is influenced by regulation

Table 2: Attributes of complex adaptive systems in environmental systems

	The physical environment	Ecosystem	Simple technology	Complex adaptive technology
System elements	Elements in the lithosphere, hydrosphere and atmosphere	Biological organisms	Artefacts	Permaculture: biological organisms Internet: websites
Relationships	Physical laws	Competition, cooperation, parasitism, symbiosis, etc.	As externally imposed: e.g. compatible technologies	Competition and cooperation
Emergent property	Climate system, hydrological cycles, soil formation	Ecological systems	Non-existent	(Quasi)permanent ecological micro system Internet: new structures for communicating, information processes, wisdom of crowd, etc.
Environment	Atmosphere: other systems of the physical Earth as well as the ecosystem Hydrosphere: the solid and gaseous physical environment as well as the ecosystem Lithosphere: atmosphere, hydrosphere and the ecosystem (plus the below-crust processes of the Earth)	The physical environment	Culture (incl. market and regulation), physical environment, ecosystem	Culture and the computer network infrastructure
Co-evolution Environment to system	Soil formation, changes in the hydrological cycles and the atmospheric cycles	Life-conditions and niches for the elements of ecosystem	No real co-evolution, but reinforced external production based on culture, market, regulation, and resources balanced with the continuous deterioration by the physical and biological environment	Permaculture: adaptation aiming stability Internet: Culture determines what knowledge is included in the system, infrastructure determines the potential for evolving tools

The interactions among the various evolving macro systems are complex and difficult to model. However, it is possible to describe what the directions of co-evolution are. Figure 3 describes the systems indicating the system-environment borders and the interaction among them. Any circle indicates a complex adaptive system. The arrows indicate the co-evolution of system and environment. Anything inside a circle is part of the system, and anything outside a circle is part of the system's environment. Technology is marked by a hexagon in order to indicate that most often material technology is not able to adaptation and self-organisation, but requires a continuous external intervention to maintain.

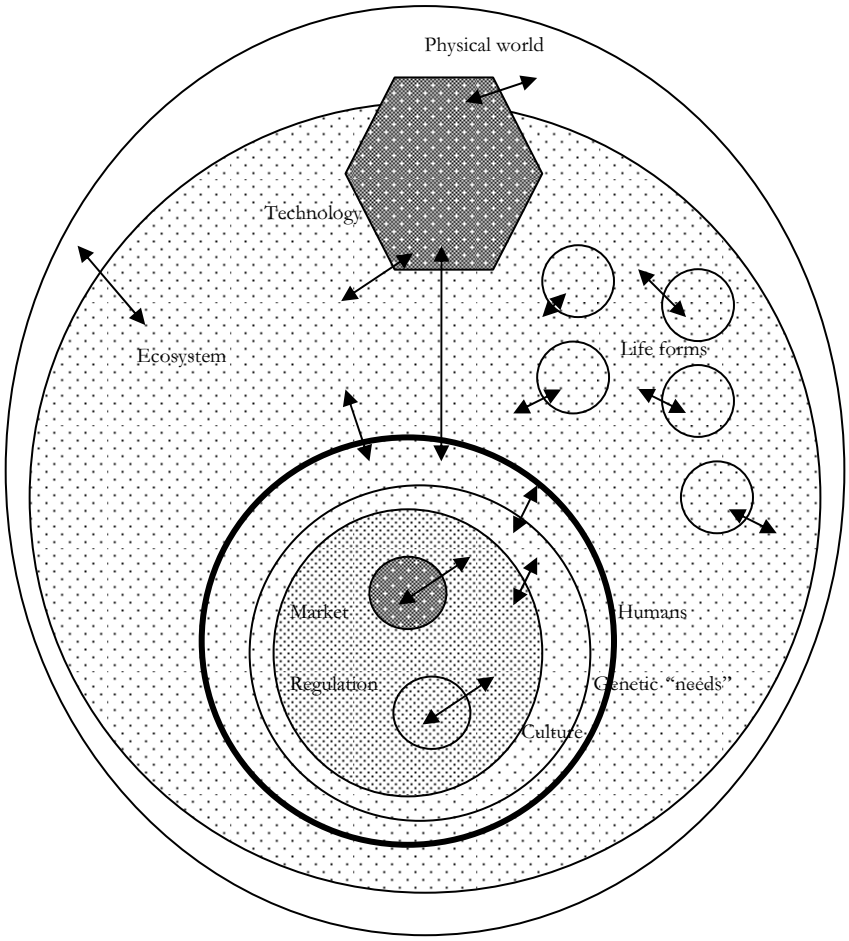

Figure 3: The co-evolution of macrostructures in the human and environmental systems - Inside a circle is the system, outside a circle is a system's environment. Denser spots indicate higher speed of change. More explanation is presented in the text above.

Figure 4 indicates the interactions among the human macrostructures and technology. Genetic motives are not changing in our timeframe of interest. The neoclassical economics concept of utility is am aggregate of cultural elements and genetic motives. The cultural elements are able to experience

change in response to changes in other systems, including the markets. Thus as described in the previous subchapters needs and utility are at some level endogenous to the market.

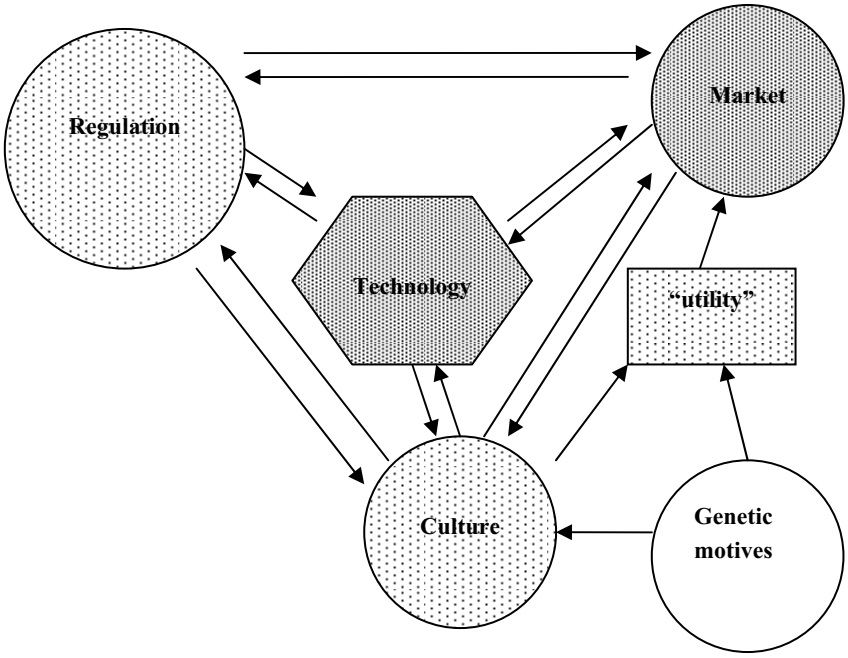

Figure 4: Interactions among human macro-systems. – Denser spots indicate higher speed of change.

As discussed in detail in the previous chapters one main cause of the problem is the drifting of cultural values and preferences influenced by market and technology. As Soros (1997) told "society has lost its anchor". Since regulation is based on general cultural values, the possibilities for regulation to intervene are quite limited. Figure 5 visualise the various processes contributing to the loss of 'social anchor', loss of stability in cultural values.

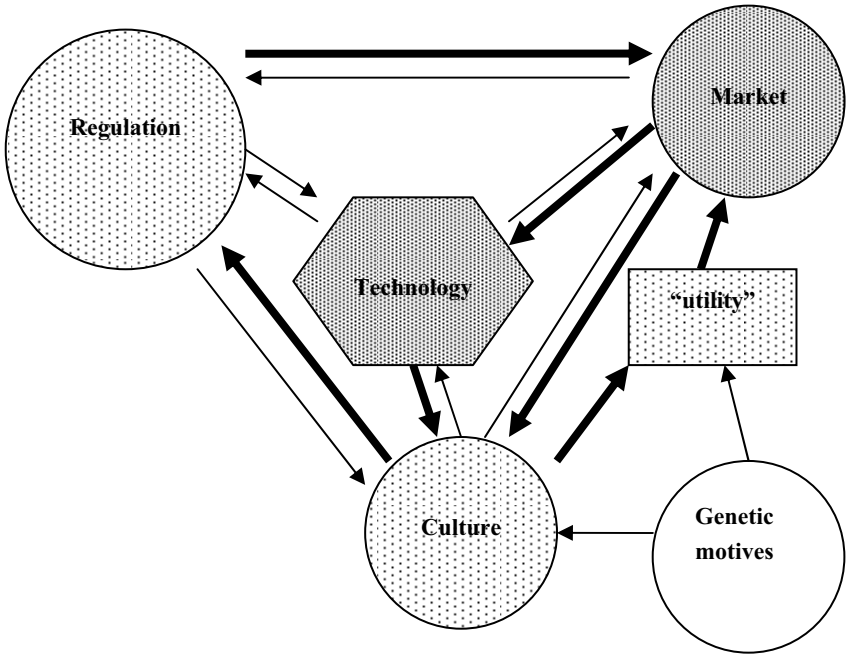

Figure 5: Market originated reinforcing loops contributing to the drift in cultural values. (Loops highlighted by bold arrows.)

4 Policy implications

Setting up a new conceptual framework for the problem of unsustainable consumption and production patterns we must reconsider the basic elements of the strategy to achieve sustainability, i.e. the goal setting and the tool set of sustainability.

4.1 Goal setting

Whether we approach sustainability from a complexity theory point of view, the goal should be set as to increase and sustain adaptability for humanity. This does not mean the maximisation of need fulfilment for all people. Needs are our adapted characteristic to motivate as for adaptive behaviour, thus they are in the tool, not in the goal dimension. If needs and need fulfilment are handled as goals, the co-evolution of needs, market and technology leads to an escalation, which have the possibility to cause a "Limits to growth"-type of overshoot and collapse scenario.

As discussed above, human motives (needs) are determined partly by genetic drives, partly by cultural programmes. However, genetic drives use relatively poor indicators to be adaptive in our current environment. Furthermore, cultural ideas, values are also rather speculative and their predominance might be dependent on other factors than utility for humans, such as controlled communication channels and compatibility with preceding ideas. Thus it can be recommended not to rely on human needs, when sustainability goals are identified, at least not in the sense of some sort of standardised, universal human rights. Rather it is recommended to realise the flexible nature of human needs and its strong impact on human behaviour and search for solutions approaching better adaptive behaviour.

In order to increase the adaptability of humanity it is difficult to draw general guidelines. As the environment of adaptation changes one or another trait can be successful or unsuccessful. As a rule of thumb humanity should aim multiple goals in the co-evolutionary process: several goals in the systems of market, regulation, technology, the ecosystem and culture. Since the complex interaction of several systems is not predictable, sophisticated planned environments are often more vulnerable than less perfected ones resulted by natural co-evolution. The goals, thus, should not aim at achieving concrete states for the various systems, but to increase in general their adaptive abilities. A general rule to achieve that is to increase the diversity of the various systems.

Increased diversity is necessary at all levels. It is not just the incubatory support of alternative technologies, which are indeed very important, but also the support of alternative institutions, business organisations, market types and social experiments. Since strengthening positive feedback loops is much more effective than trying to put on breaks on unfavourable processes, it is much easier to achieve results by supporting non-profit, service and community oriented business organisations (e.g. cooperatives or similar yet uninvented organisational forms) than trying to direct for-profit organisations to behaviours that are not in line with the selection pressure forming their evolution.

Another general rule is that systems need to be able to stay below too much interconnectedness in order to remain flexible enough to adapt to changes. Thus systems need to be optimised to the level of interconnectedness making them best able to adapt to changing environments. This means especially for human market and infrastructural systems that we should aim to decrease interconnectedness.

Summarising recommended goals for SCP:

- Need fulfilment is a tool not a goal for adaptive behaviour:
- Individuals need to develop a reflective self-consciousness to see objectively their needs and being able to decide whether to behave according to them or different;
- Multiple goals for increased adaptability in several systems: market, regulation, technology, eco-system and culture;
- Increased system diversity needs to be stimulated;
- Level of interconnectedness needs to be optimised for maximum adaptability.

4.2 Tool set

4.2.1 Indicators

A set of indicators needs to be developed reflecting the sustainable consumption and production goals. As described above, adaptability requires multiple goals, thus aggregating indicators too much hijacks efforts towards sustainability. Many system archetypes provide different results in the short term and in the long term. To avoid the trap of such system archetypes indicators should inform about expected development on the longer term. Since causality is not deterministic, predicting impact is only possible through a risk management approach, i.e. predicting probabilities.

Summarising the characteristics of recommended set of indicators:

- Indicators should measure multiple goals, not being aggregated too much
- Indicators should inform about systems' adaptability
- Indicators should measure longer term impacts
- Indicators should predict probabilities

In order to provide more concrete examples for the application of indicators alternatives for LCA and DPSIR are proposed in the next subchapter.

4.2.2 Environmental problem description

An underlying idea of this paper is that policy making is happening in a system, policy making itself being part of it, where the various components are in a non-linear, complex interrelationship. This arrangement causes balancing and reinforcing feedback loops among system components. Thus a policy intervention can only be assessed if we can understand the long range of changes it provokes through the various causal chains, often including the practice of policy making itself.

Already in the early years of the wider international recognition of environmental issues, the necessity of a casual framework for studying environmental problems has emerged. A widely used simplification and adaptation of Rapport and Friend's (1979) early "stress-response" model is the Organization for Economic Cooperation and Development's "Pressure - State - Response" (PSR) framework (OECD, 1991, 1993).

In the DSR framework, the term "pressure" has been replaced by that of "driving force" in order to accommodate more accurately the addition of social, economic, and institutional indicators. In addition, the use of the term "driving force" allows that the impact on sustainable development may be both positive and negative as is often the case for social, economic, and institutional indicators. The DSR framework is actually a matrix that incorporates three types of indicators horizontally and the different dimensions of sustainable development vertically, namely social, economic, environmental, and institutional (OECD, 1996).

In recent years, the EEA has broadened its perspective dealing with environmental issues from focussing on pressures, states and impacts, to involving drivers and the potential responses as well, developing the DPSIR methodology (EEA, 1999).

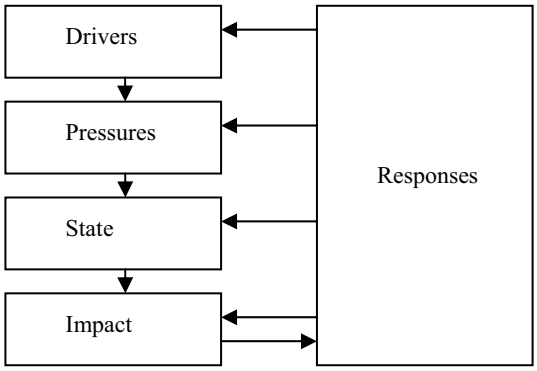

Figure 6: The DPSIR framework for reporting environmental issues
(Source: EEA, 1999)

The original PSR model had distinct components for pressures (human behaviour), state (state of the environment) and responses (regulation). DPSIR has already integrated society, environment and economy as the three different dimensions of sustainability. However, while DPSIR is now able to handle many dimensions, putting the same trends to different places have weakened its ability to correctly identify causal interactions.

Contrary to the DPSIR approach, in system thinking components are not defined as drivers or impacts in relation to one selected element, but cause and effect relationship is extended to all elements. In fact, the system is better described as a web of relationships, where different components can have multiple causal roles, than some sort of hierarchical structure. For example, a tendency might be the result of another one and in the same time the cause of a third one. Even regulation is not an external, independent "responder", but also is effected by many of the system components, it is intended to be regulating.

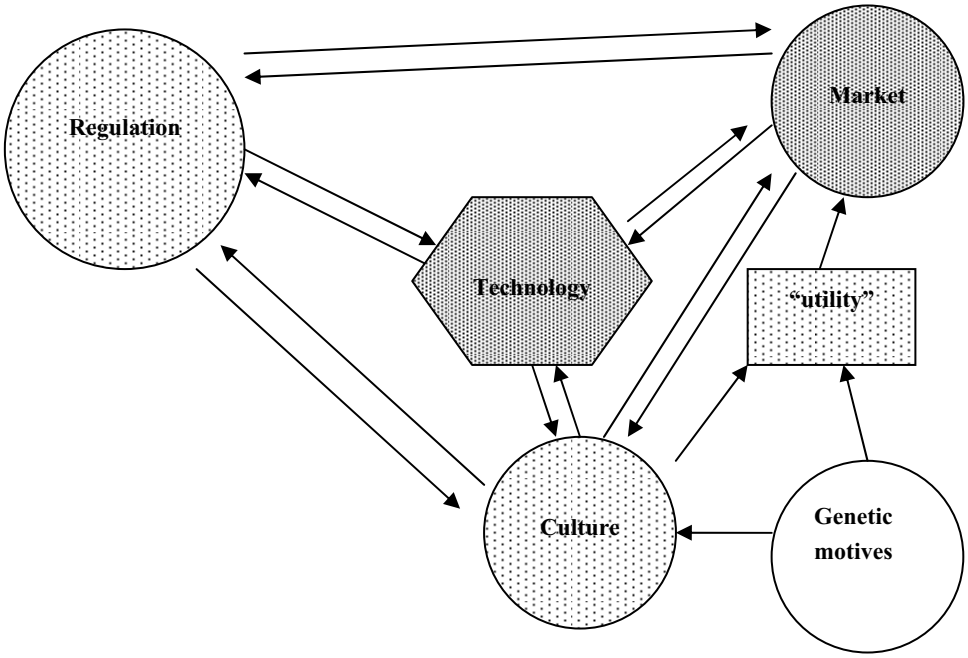

Figure 7: A co-evolutionary framework of social systems

The suggested approach is that the different trends are not labelled (as pressures, drivers, etc.) before the causalities are described, but the observed trends are put in the causality model of evolving systems and the co-evolution of the whole system is described. Then, longer term prediction of possible outcomes with probabilities in the whole system will define whether a trend is problematic or advantageous, or else maladaptive or adaptive.

4.2.3 Measuring environmental impact

Life-cycle assessment provides relatively little and controversial information about the long term impact of consumption and production activities on the environment. It is not able to describe how much of a certain product will be consumed, whether it creates needs, provokes the development of a new technology, contributes to cultural values, which are pro-environment or careless. It cannot measure whether a technology will be sold in billions of pieces as a fad or will become an efficient way of fulfilling basic needs. Because of it controversial method of aggregation, even its value to describe the environmental pressure by a consumed unit is questionable (and often questioned).

The authors suggest putting this approach in a wider framework in order to be able to describe the impact of consumption events on the longer term evolution of culture, technology and consequently the environment.

According to the authors it is much more important for a sustainability point of view if a consumption event leads to less or more diverse cultural values, escalating need patterns, etc. than the direct, short term environmental impact of the consumption of one unit.

5 Overall conclusions

There is evidence that many human and environmental systems are co-evolving complex adaptive systems. These systems are nested, such the ecosystem, the organism, but also the organs and cells are complex adaptive systems. Similarly in our social structures our shared knowledge of problem-solving, i.e. culture is evolving similarly than included systems of the market or regulation. Besides those the human mind is a complex adaptive system with genetically or culturally inherited computational mechanisms forming a coherent structure, the Self.

The recognition of such a web of systems makes traditional linear policy making obsolete. Setting up a goal and executing actions towards it will result in a whole chain of adaptations possibly contributing to unexpected results. Most importantly for a sustainability point of view we need paradigm shift about our nature of consciousness. While humans are conscious about their consciousness, few are conscious about the *how* and *why* of their consciousness. Our needs are inherited, genetically or culturally, as well as our whole Self is an aggregation of inherited traits. This reflexive self-consciousness might assist in avoiding absolutising our needs and thus avoid the suffering related to unfulfilled needs. Needs should be regarded as tools, which used to be adaptive at some point of human or pre-human history and might be equally adaptive or maladaptive today. Therefore needs have no place in the goal dimension of sustainability. By focusing on the fulfillment of needs will result in escalating patterns of needs as well as consumption and production.

The goal dimension of sustainability has to deal with a sustained ability to adapt human systems to changing environments (including for example depleting resources). Successful adaptive strategies aim multiple goals in all relevant external systems and do that through an increased diversity of tools so that the failure of some of them will not result in a total breakdown. Not just technologies, but also organizational structures, institutions and social alternatives need to be supported in order to achieve a high level of diversity and adaptive ability in these systems.

These alternative structures have the important task to decrease current high level of technological and market interconnectedness, which makes these systems inflexible and thus globally vulnerable.

Because positive feedback loops are much easier to strengthen than to put control on unfavourable processes, it is recommended to put effort in cultivating adaptive practices rather than being busy with the problem shifting race of regulatory and technological co-evolution. Fighting unfavourable processes gives them importance since human attention is one of the world's scarcest resources and the system and subsystems of culture is based on this resource. Certainly when unfavourable processes seriously distort necessary balance it must be restored, but otherwise money and attention needs to be paid quickly on promising alternatives.

Certainly, for a useful action plan, the responsible actors need to be identified. The illusion that national governments can solve this problem has disappeared. The biggest source of norms today is not the regulator, but the market and mass media. With the current for-profit, investment directed market forms it is not expected that market actors will seriously change their strategy. In order to realise enough ignorance of unfavourable processes and enough support of alternatives, a non-elitist, mass paradigm shift seems to be

inevitable. Whether there are available tools to achieve such a result through grass-root organisation, emerging technologies (such as the potentials in Internet as a self-organising system) or else opens new research questions out of the scope of this paper.

References

Abel, Th. (1998) *Complex Adaptive Systems, Evolutionism, and Ecology within Anthropology: Interdisciplinary Research for Understanding Cultural and Ecological Dynamics*, Georgia Journal of Ecological Anthropology 2: 6-29.

Arthur, W.B. (1989) *Competing technologies, increasing returns, and lock-in by historical events*. The Economic Journal, 99: 116-131.

Arthur, W.B. (1994) *Increasing Returns and Path Dependence in the Economy*. Michigan University Press, Ann Arbor, MI.

Axelrod, R. and W. Hamilton (1981) *The evolution of cooperation*. Science 211: 1390-1396

Baudrillard, J. (1988) *Selected Writings*, ed. Mark Poster, Stanford; Stanford University Press

Bernard, L.C., Mills, M., Swenson, L., Walsh, R.P. (2005) *An Evolutionary Theory of Human Motivation*, Genetic, Social, and General Psychology Monographs, 131(2): 129–184

Bertschinger, N.; E. Olbrich, N. Ay, J. Jost. (2007) *Autonomy: an Information-Theoretic Perspective*, Special Issue of BioSystems, to appear http://www.santafe.edu/research/publications/workingpapers/06-10-035.pdf

Bowles, S. (1998) *Endogenous preferences: the cultural consequences of markets and other economic institutions*. Journal of Economic Literature, 36(1): 75-111

Chan, S. (2001) *Complex Adaptive Systems*, MIT, Research Seminar in Engineering Systems, Course Notebook, http://web.mit.edu/esd.83/www/notebook/Complex%20Adaptive%20Systems.pdf

Csikszentmihalyi, M. (1993) *The Evolving Self*. HarperCollins

Darwin, C. (1859) *The Origin of Species by Means of Natural Selection*, first edn, John Murray, London

Dawkins, R. (1986) *The Blind Watchmaker*. Longman, London

Dawkins, R. (1989) *The Selfish Gene*, new edn, Oxford University Press, Oxford

Dobzhansky, Th. (1937) *Genetics and the Origin of Species*. Columbia University Press, New York

EEA (1999) Environmental indicators: Typology and overview, Technical report No 25. Available at http://reports.eea.eu.int/TEC25/en/tab_content_RLR

Ehrlich P. (1991) *Coevolution and its applicability to the Gaia hypothesis*. In: Schneider SH, Boston PJ, editors. Scientists on Gaia. Cambridge: MIT Press. p 19–22.

Ehrlich PR, Raven PH. (1964) *Butterflies and plants: a study in coevolution*. Evolution 18: 586–608

Falk, Armin, and Michael Kosfeld. (2004) *Distrust - the hidden cost of control*. IZA Working Paper 1203

Futuyma D, Slatkin M, editors. (1983) *Coevolution*. Sunderland (MA): Sinauer

Gneezy, Uri, and Aldo Rustichini. (2000) *A fine is a price*. Journal of Legal Studies, 29(1): 1-17

Hamilton, W. D. (1964) *The genetical evolution of social behaviour*. Journal of Theoretical Biology 7: 1-52

Hayek, F., (1967) *Notes on the Evolution of Systems of Rules of Conduct*. In Studies in Philosophy, Politics and Economics, Routledge and Kegan Paul, London, pp. 66-81

Hofstede, G. (2001*) Culture's consequences: Comparing values, behaviors, institutions, and organizations across cultures*. Thousand Oaks, CA: Sage

Hutton J. (1788) *Theory of the Earth; or an investigation of the laws observable in the composition, dissolution, and restoration of land upon the globe*. R Soc Edinb Trans 1:209–304

Lenton, T.M. and van Oijen, M. (2002) *Gaia as a complex adaptive system*, Phil. Trans. R. Soc. Lond. B (2002) 357, 683–695

Levin SA, Barrett S, Aniyar S, Baumol W, Bliss C, Bolin B, Dasgupta P, Ehrlich P, Folke C, Gren I-M, Holling, C.S.; Jansson, A.; Jansson, B-O; Mäler, K-G; Martin, D.; Perrings, Ch.; and Sheshinski, E. (1998) *Resilience in natural and socioeconomic systems*. Environ Dev Econ. 3:225–36.

Levin SA. (1983) *Some approaches to the modeling of coevolutionary interactions*. In: Nitecki M, editor. Coevolution. Chicago: University of Chicago Press. p 21–65.

Levin, S.A: (1998) *Ecosystems and the Biosphere as Complex Adaptive Systems*, Ecosystems 1: 431–436

Lieberman, D, J. Tooby and L. Cosmides (2007) *The architecture of human kin detection*, Nature 445: 727–731

Lovelock JE. (1972) *Gaia as seen through the atmosphere*. Atmos Environ 6:579–80

Marcia, J. E. (1966) *Development and validation of ego identity status*. Journal of Personality and Social Psychology, 3: 551-558.

Margulis L, Lovelock JE. (1974) *Biological modulation of the Earth's atmosphere*. Icarus 21:471–89

Matthews, R.C.O. (1984) *Darwinism and economic change*. In Economic Theory and Hicksian Themes. D.A. Collard, N.H. Dimsdale, C.L. Gilbert, D.R. Helm, M.F.G. Scott, A.K. Sen (eds.), Oxford University Press, Oxford.

Mauboussin, M.J. (2002) R*evisiting Market Efficiency: The Stock Market as a Complex Adaptive System*, Journal of Applied Corporate Finance, 14(4), Winter, 2002

Mayr, E. (1942) *Systematics and the Origin of Species*. Columbia University Press, New York

Michaelis, L., (1997) *Technical and behavioral change: Implications for energy end-use*. In Energy Modelling: Beyond Economics and Technology. B. Giovannini, A. Baranzini (eds.), International Academy of the Environment, Centre for Energy Studies, University of Geneva, Geneva

Mollison, B. and Holmgren, D. (1978) *Permaculture One*. Transworld Publishers (Australia)

Norberg, J. (2004) *Biodiversity and ecosystem functioning: A complex adaptive systems approach*, Limnol. Oceanogr., 49(4, part 2): 1269–1277

Norgaard, R.B. (1994) *Development Betrayed: The End of Progress and a Coevolutionary Revisioning of the Future*, Routledge, ISBN 0415068622

OECD (1991) Environmental Indicators: a preliminary set, Paris, OECD.

OECD (1993) OECD core set of indicators for environmental performance reviews. A synthesis report by the group on the state of the environment OECD, Paris

OECD (1996) Developing OECD Agri-Environmental Indicators. Mimeograph. July 30. Organization for Economic Cooperation and Development. Paris, France

Ormerod, P. (2001) *Butterfly Economics : A New General Theory of Social and Economic Behavior*, New York, NY, U.S.A. Pantheon Books. 2001. (ISBN: 0465053564)

Price, M.E., L. Cosmides and J. Tooby (2002) *Punitive sentiment as an anti-freerider psychological device*, Evolution and Human Behavior 23: 203–231

Putnam, R. (2000) *Bowling Alone: The Collapse and Revival of American Community*. New York: Simon & Schuster

Rapport, D. and A. Friend: (1979) Towards a comprehensive framework for environmental statistics: a stress-response approach. Statistics Canada Catalogue 11-510 (Minister of Supply and Services Canada, Ottawa)

Rodríguez-Sickert, Carlos; Ricardo-Andrés Guzmán, and Juan-Camilo Cárdenas (2007) *Institutions Influence Preferences*, SFI Working Paper, http://www.santafe.edu/research/publications/workingpapers/07-08-019.pdf

Schumpeter, J., (1943) *Capitalism, Socialism and Democracy*. Harper & Brothers, New York, NY

Shove E, Warde A. (1998) *Inconspicuous Consumption: the Sociology of Consumption and the Environment*, Manuscript, Centre for Science Studies and Department of Sociology Lancaster University. http://www.lancs.ac.uk/fss/sociology/papers/shove-wardeinconspicuous-consumption

Shove, E. (2003) *Comfort, cleanliness and convenience: the social organization of normality*, Berg Publishers, Oxford and New York, 2003, ISBN: 1859736300, 224 pp.

Simpson, G. G. (1944) *Tempo and Mode in Evolution*. New York: Columbia Univ. Press

Soros, G. (1997) *The Capitalist Threat*, Atlantic Monthly, 279(2)

Sotarauta, M. & Srinivas, S. (2005) *The Co-Evolution of Policy and Economic Development: A Discussion on Innovative Regions*. MIT IPC Local Innovation Systems Working Paper 05-001 (Evolutionary Theories in the Social Sciences WP 05-001) http://www.etss.net/index.php/weblog/workingpapers/

Teilhard de Chardin, P. (1959) *The Phenomenon of Man*. English translation published by William Collins Sons & Co., London

Tooby, J. & Cosmides, L. (1992) *The psychological foundations of culture*. In J. Barkow, L. Cosmides, & J. Tooby (Eds.), The adapted mind. New York: Oxford University Press

Tooby, J., Cosmides, L. & Barrett, H. C. (2005) *Resolving the debate on innate ideas: Learnability constraints and the evolved interpenetration of motivational and conceptual functions*. In Carruthers, P., Laurence, S. & Stich, S. (Eds.), The Innate Mind: Structure and Content. NY: Oxford University Press

van de Vliert, E. (2007) *Climatoeconomic Roots of Survival Versus Self-Expression Cultures*. Journal of Cross-Cultural Psychology, 38(2): 156-172

van den Bergh, J.C.J.M., A. Ferrer-i-Carbonell and G. Munda (2000) *Alternative models of individual behaviour and implications for environmental policy*. Ecological Economics 32(1): 43-61

Waldrop, M., (1992) *Complexity*. New York, NY, Touchstone/Simon & Schuster

Whiten, A., Spiteri, A., Horner, V., Bonnie, K.E., Lambeth, S.P., Schapiro, S.J., de Waal, F.B.M. (2007) *Transmission of Multiple Traditions within and between Chimpanzee Groups*, Current Biology 17: 1038–1043