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THE 'NATURE' OF DEVELOPMENT STUDIES
An Ecological Perspective on Uneven Development

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Introduction: The 'Nature' of Development Studies

This special issue is an effort to align some of the core concerns within development studies with other fields of enquiry where 'nature' plays a predominant role in the broader development discourse. Development studies, in its strictly classical sense, concerns itself with analysing and understanding processes of social change (economic, political, cultural) but also with the planning and managing of approaches for development interventions for a just and equal world. Scholars of development studies maintain that much of the inequalities and uneven distribution of wealth and problems is a consequence of the way the world's political and economic structure is organised (Crush 1995; Rist 1997; Cowen/Shenton 1996; Kothari 2005).

Incidentally, these concerns have not only been the prerogative of scholars of development studies but have been raised by other fields of research as well, namely, ecological economics, social and human ecology, political ecology and human geography. What makes these approaches different is that 'nature' and 'ecology' plays a vital role in their analysis to reveal mechanisms of uneven development and unequal exchange. For example, social ecology views ecological and material impoverishment as embedded in the ways humans interact with their environment at multiple scales. Ecological economics has attempted to illustrate 'ecological' unequal exchange between the industrial core and the peripheral hinterlands as well as between the North and the South, and the impact this has on development options. Political ecology, on the other hand, mostly occupies itself with understanding the relationships between the degradation of resources and marginalisation centred on access and rights over resources, often leading to social conflicts over natural resources. In most of these analyses, biophysical units such as mass, energy, land and time are proposed as a measure as opposed to the classical monetary units to explain unequal exchange and environmental justice.

As it appears, there seems to be a fairly low level of cross-fertilisation between classical development studies and other interdisciplinary approaches that include ecology as a relevant variable in determining some of the core explanations of poverty and uneven development. This is not to say that the development scholars have been entirely dismissive on the question of nature. Since the late 1990s, there have been attempts to include global ecology in the analysis of the world system perspective, an influential theoretical and analytical paradigm within development studies. According to Chew (1997), the world system approach at first included natural causative forces. Fernand Braudel, especially in his earlier works such as *The Mediterranean and the Mediterranean World in the Age of Philip II* (Braudel 1972), describes the specifics of that society and economy as it grew from the nature of the land. However, world system theorists who followed Braudel failed to include nature in their analysis. Dunlap and Catton, Jr. (1994) maintain that between 1985 and 1990, world system theory, following attacks from voluntarists, historicists, feminists and post-modernists, was beginning to lose favour among social scientists and attention was turned increasingly towards micro-level politics of identity. This was precisely the period during which the environmental debate intensified with our growing knowledge of the ozone hole, destruction of the rain forests and global warming. Stephen Bunker (1985), working on the extractive economy of the Brazilian Amazon, was a lone voice attempting to combine environmental and energy issues with the central issues of world system theory. Prominent world system theorists during this period (such as Immanuel Wallerstein, Samir Amin, André Gunder Frank, Christopher Chase-Dunn and Eric Wolf) treated nature as external and as a backdrop to what they regarded as the principle engine of change, that is, social relations in general and capitalism in particular (Chew 1997).

Since the late 1990s, however, environmental issues have gained prominence within world system theory.[1] For example, Chew (1995) pointed out that the decline of large empires throughout history was attributed to massive deforestation and land degradation. Based on a 5,000-year historical analysis of the rise and fall of the centres of accumulation, Chew (2000: 216) argues that "the limits of Nature become also the limits of the system […] the interplay between the limits of Nature and the trends and dynamics of the world system defines ultimately the historical tendencies of world system evolution". Sanderson (1995) also explicitly incorporates environmental factors in order to explain the succession of social forms throughout history. Similarly, Chase-Dunn and Hall (1997) postulate an 'iteration model' that explains ecological degradation within the context of world systems evolution. The model identifies recurring processes linking population growth, ecological degradation, conflict, hierarchy formation, and economic intensification.

The publication of *Ecology and the World-System* (Goldfrank et al. 1999) may be seen as a concerted attempt towards the 'greening of the world system theory'. The organisation of the volume emphasises three ways in which environmental analysis intersects with the long-standing concerns of scholars working within the world systems framework: (1) the emergence of threats to the global environment and of ecological limits to the sustainability of capitalism; (2) the various environmental impacts among different parts of the world economy; and (3) replication and variation among environmental social movements in the contemporary world. In the same volume, Wallerstein (1999) argues that contemporary environmental crisis is attributed to the necessity for entrepreneurs to externalise costs and to the lack of incentives for them to make ecologically sensitive decisions. Moore (2000) has argued that the emergence of capitalism marked not only a decisive shift in the arenas of politics, economy, and society, but a fundamental reorganisation of world ecology, characterised by a 'metabolic rift'.[2] Moore argues that as new geographical areas were included in the world system under the logic of capitalism, there was a cyclical restructuring and reorganising of the agro-ecological system that intensified exploitation of nature for capital accumulation.

World system theorists have also reacted to neoclassical economists who argue that countries on their path to development will face severe environmental degradation at first. Only after a certain point in economic development will they reach a 'turning point' that signals a move towards improved environmental performance. This hypothesis, termed the *Environmental Kuznets Curve* (EKC) (Kuznets 1955), is challenged by several world system theory scholars. Roberts and Grimes (1997), for example, in an examination of the historical trend over 30 years for national carbon intensity, report that the environmental Kuznets curve does not represent a historical trend, but is merely a cross-sectional pattern that emerged in the 1980s and that is actually likely to worsen. Burns et al. (1997) discovers that the core and semi-core nations respectively emit the highest amounts of carbon dioxide and methane, the two most important greenhouse gases known to cause global warming. More specific studies on issues such as deforestation and global warming have also been taken up within the framework of the world system perspective. For example, Kick et al. (1996) conclude that whether core countries import or export forest products, they experience less deforestation as a result of their reforestation practices. By contrast, semi-peripheral countries lose either way (by exports or imports), since most of the timber that is imported is utilised in the building of infrastructure to exploit their own forests to meet export demands. This is clearly not a complete list of scholars engaged in analysing environmental issues within world system theory. A few others of interest are: Frey (1993), Barnham et al. (1994), Cicantell (1994), Smith (1994), Gellert (1996), Barbosa (1996), Roberts (1996), Grimes and Roberts (1995) and Jorgenson and Kick (2003).

Apart from research within world system theory, the material basis of social systems has been recognised by development scholars, especially when dealing with rural livelihoods and natural resource conservation. Andrea Kobler's (2009) excellent review of three prominent journals of development studies[3] from the 1970s onwards shows a steady increase in the number of articles that explicitly address nature and ecology in their analysis. The theme of natural resource conservation, their management and governance (with respect to agricultural and forest land, water, livestock, wildlife, and fisheries) was addressed quite explicitly in 6 papers in the 1970s, 19 in the 1980s, 46 in the 1990s, and 81 in the 2000s. These were discussed predominantly with respect to rural livelihoods, management of the commons, the importance of recognising traditional ecological knowledge, institutions and environmental governance. The issue of environmental degradation and crisis was reflected in 2 papers in the 1970s, 4 in the 1980s, 8 in the 1990s and 14 in the 2000s. These accrued mostly to land mismanagement and deforestation leading to soil erosion and desertification. An increasing number of papers in the last two decades focussed on urban pollution and waste generation. A few papers discussed energy security with respect to oil crisis, future availability and price of fossil fuels and its implication for the developing countries, but also exploring options for renewable energy. With respect to the theme of energy, 5 papers were published in the 1970s, 7 in the 1980s, 3 in the 1990s, and 7 in the 2000s. Environment-related conflicts and access to natural resources also featured in these three journals. The authors attributed the analysed conflicts largely to inappropriate policies and higher level interventions with respect to natural resource management. While the theme of environment-related conflicts was only marginal in the first three decades (7 papers in all), some 20 papers appeared in the 2000s with an explicit reference to political ecology. More recently, new themes have emerged within development studies as reactions to broader discourses concerning the environment. Among them, in the 2000s, the theme of natural disasters and vulnerability (6), environmentalism (6), corporate social responsibility (7) and environmental migration (2) seem to be most prominent.[4]

Within the discourse of 'sustainable development', there is evidence of pioneering efforts by development scholars culminating in their active participation at the 1992 UN Conference on Environment and Development held in Rio de Janeiro. What followed thereafter was a disillusionment and scepticism over how the debate around sustainable development had evolved. The term itself began to be criticised as being more of a slogan than a theoretical concept guiding even development. Mainstream sustainable development, was perceived as regarding economic growth not as a problem but as a solution, ignoring concerns raised by the 'limits to growth' and 'zero growth' debates of the 1970s (Redclift 1987; Adams 1990; Sachs 1995; Rist 1997). To scholars of development, sustainable development is inextricably linked to rural livelihoods and the access and control of resources by the rural poor. Meanwhile, a popular approach to sustainable development drew more from the natural sciences rooted in northern environmentalism. Sustainability became synonymous with the conservation and management of the global and regional environment with respect to the earth's ecosystems, land use, biodiversity, and climate.[5] A large number of quantifiable indicators began to be proposed to measure sustainability (Hak et al. 2007). Development scholars critiqued the modernist dogma of 'rational utilization' and 'maximizing human benefit' through technocratic, managerial and capitalist ideologies (Adams 1995). In other words, to scholars of development studies, sustainable development was at best environmental management through neo-classical and neo-liberal market mechanisms made possible through the appropriate valuation and pricing of natural resources (Woodhouse/Chimhowu 2005). Thus, the initial enthusiasm of development studies scholars within the sustainability debate resulted in a backlash. However, the natural environment continued to feature in several of their publications as noted above, but they downplayed the use of the term 'sustainable development'. While in the 1990s some 15 papers appeared with this term in the three journals reviewed, the use of the term declined drastically in the last decade, and when they did, the term was severely criticised as being vague.

Indeed, ecological issues, the environment and natural resource management are increasingly acknowledged by development scholars in their quest for an equitable world. Whether in critiquing popular paradigms or defining their own agenda of sustainable rural livelihoods, development studies scholars have not remained oblivious to the relevance of nature and the environment in the context of development. However, there is still a great potential to enhance conceptual soundness and methodological insights that might be of advantage to development studies. An increased cross-fertilisation of development studies with other interdisciplinary approaches engaged with similar concerns and ideologies may only be to its advantage. This special issue seeks to introduce some of these approaches and explore the extent to which they can be useful in understanding the process of uneven development, where nature is a major stakeholder. The contributors of this volume by and large attribute unequal exchange as a key mechanism that drives uneven development. In doing so, most contributions emphasise biophysical units as a measure, and thus refer to 'ecological' unequal exchange as it occurs within the world economic order and international trade relations.

The first two papers in this special issue are conceptual in nature. Inge Røpke introduces the emerging field of ecological economics and explores its potential for addressing some of the concerns within development studies. Alf Hornborg argues that unequal exchange between the rich and poor countries takes place by means of an asymmetric transfer of biophysical resources such as energy, matter, embodied land and labour. This is not only fundamental to understanding development gaps, but also the role of 'technology' as a social redistribution process that presupposes unequal exchange. The following two papers attempt to empirically illustrate the notion of ecological unequal exchange using a number of case studies. Simron Jit Singh and Nina Eisenmenger propose the concept of 'social metabolism' and its operational tool, Material Flow Accounting (MFA) as a means to illustrate ecological unequal exchange by tracking flows of matter in international trade. Anke Schaffartzik introduces the Ecological Footprint (EF) concept and examines how trade is accounted for in EF analysis in order to gauge the utility of the ecological footprint as a tool for quantifying ecological distribution conflicts. The special issue concludes with the contribution of Michael Hauser and colleagues, who take on a complementary approach suggesting local level action as a means to address uneven development. Using a case study from Western Uganda, they argue for a community-led innovation approach in improving smallholder agriculture and rural livelihoods. In other words, uneven development may not only be addressed at the level of macro-level structures, but must be complemented by local action.

1 In 1997, the Political Economy of the World System (PEWS) section of the American Sociological Association (ASA) had as their conference theme: The Global Environment: A World System Perspective.
2 Developed in preliminary form by Marx and reconstructed by Foster (1999), the concept of 'metabolic rift' illuminates the rupture in nutrient cycling between the country and the city, and within regions on a global scale, in historical capitalism. With the transition to capitalism, products flowed into the cities which were under no obligation to return the wastes to the point of origin. Nutrients were pumped out from one ecosystem in the periphery and transferred to another in the core until its relative exhaustion rendered it unprofitable (Moore 2000).
3 These are: Third World Quarterly, Development and Change, and Journal of Development Studies.
4 The data presented here is a reconstruction from the empirical work of Andrea Kobler (2009), carried out under the supervision of the first editor. The categories presented here are not watertight and there are some obvious overlaps. However, the decision on categorisation of these papers was based on their dominant theme.
5 The four highly influential global environmental change programmes (GEC) are: International Geosphere-Biosphere Programme (IGBP), International Human Dimensions Programme (IHDP), World Climate Research Programme (WCRP), and DIVERSITAS – an international programme for biodiversity science.

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Inge Røpke

Society's Nature: Ecological Economics and the Combined Challenge of Environment and Distribution

The paper introduces the emerging field of ecological economics and evaluates its potential for addressing some of the concerns within development studies. It takes as its point of departure the study of the relationship between nature and society that emerged in the wake of the environmental discourse in the 1960s. In the first section, a new perspective in the study of the interaction between society and nature is briefly outlined. Thereafter, the field of ecological economics is discussed as a specific example of this new perspective, followed by its potential link to the development debate, in particular the combination of the environmental and distributional issues and the challenges therein. Finally, the paper reflects on the persuasive potential of ecological economics in relation to politics.

1. The breakthrough of a new perspective

In the wake of the environmental discourse that emerged in the 1960s, a new research perspective began to take shape. Whereas researchers from natural sciences, foremost biologists, were instrumental in encouraging environmental discourse, the social sciences tended to be rather more reactive. The most obvious reaction was to apply well-known theoretical approaches with which they were already familiar to the new phenomena: sociologists started to study environmental movements as they studied other social movements, economists studied environmental externalities as they studied other welfare economic disturbances, psychologists studied how people reacted to environmental risks as they studied reactions to other stresses, and so on (Pearce 2002; Dunlap 1997). However, the new problematic relationship between society and nature also inspired some researchers – from both social and natural sciences – to apply a different perspective, as they began to consider social processes in the way that natural sciences do, for example by analysing flows of energy and matter, or applying the notion of metabolism to social systems. This biophysical perspective had a number of forerunners dating back to the nineteenth century, but the real breakthrough did not come until the late 1960s (Martinez-Alier 1987; Fischer-Kowalski 1998; Røpke 2004). In the following, the perspective is mostly related to economic thinking, although it was influential in other social sciences as well.

It may seem self-evident to state that human societies are as much nature as they are culture: human societies are embedded in nature, and social processes are also always natural processes in the sense that they can be seen as biological, physical and chemical processes and transformations. However, our understanding of human societies as natural phenomena is not very well-developed. This persistent lack of understanding is related to the institutionalised division between natural sciences on the one hand, and social sciences and the humanities on the other (Costanza et al. 1997a). From the time of the foundation of modern science up until the appearance of modern-day environmental problems, only a few scientists have crossed this line – such as the Physiocrats, who based their description of the economy on the productivity of land, and various individuals who made early use of thermodynamics in order to describe the economy in terms of energy. But the typical pattern has been that the economy has first and foremost been described in terms of money, prices and the flow of goods, while biologists, for example, have restricted themselves to describing ecosystems that are as isolated as possible from human influence. With the breakthrough of the new concept of 'environmental problems' in the 1960s, this pattern began to be gradually broken down. Some systems ecologists began to apply their analyses of the flows of energy and materials in ecosystems to human societies as well, while a number of physicists began to establish an energy perspective on the economy, just as some economists began to work with thermodynamic concepts and analyses of material flows (Daly 1968; Ayres/Kneese 1969; Georgescu-Roegen 1971; Odum 1971; Røpke 2004). The concept of metabolism also began to be applied to human societies (Fischer-Kowalski/Weisz 1999).

The fascinating – and environmentally problematic – characteristic of human societies seen as natural phenomena is the ability of human beings to utilise far larger amounts of energy and materials than they need from a somatic point of view. The term 'endosomatic energy consumption' refers to the energy consumption necessary to keep a person alive under given climatic conditions, while 'exosomatic energy consumption' refers to all the extra consumption that follows from our way of life. A particular characteristic of human beings is that they may have an exosomatic energy consumption that is many times larger than their endosomatic energy consumption. If one compares a human society with an anthill, this metaphor is limited by the fact that the human 'anthill' is not required to comply with a set form, but can be constructed in numerous different ways which may increase the use of energy and materials as well as greatly multiplying the appropriation of land, water and air per person. This becomes even more problematic if most of this exosomatic energy as well as materials are obtained from non-renewable geological stocks (fossil fuels, minerals, ores, metals, etc.), leading to sustainability problems on the input side (eventual resource scarcity) as well as on the output side (creating wastes that cannot be effectively absorbed by nature).

When this perspective had its modern breakthrough, several sub-disciplines were influenced in turn and new interdisciplinary fields emerged, such as social and human ecology, ecological anthropology, environmental history, environmental sociology and ecological economics. I concentrate here on ecological economics.

2. Ecological economics

Although this new perspective was formulated in its modern version in the late 1960s, it took about twenty years before it was institutionalised through the creation of The International Society for Ecological Economics in 1988. In the meantime, the welfare economic approach to the study of environmental problems had become well established as environmental economics and during the following years, ecological economics developed to some extent in a critical dialogue with environmental economics. There is no authoritative version of the research programme of ecological economics, but it makes sense to talk about a core of basic ideas. Different authors present ecological economics in different ways (e.g. Martinez-Alier 1987; Costanza et al. 1997a, 1997b; Söderbaum 2000; Common/Stagl 2005; Daly/Farley 2004; Martinez-Alier/Røpke 2008; Eriksson/Andersson 2010), but almost all agree that the same idea is fundamental: the human economy is embedded in the biosphere, which is a closed system. This is what Herman Daly calls the preanalytic vision of ecological economics (Daly/Cobb 1989). Related to this idea is the presupposition that the human economy can take up more or less 'space' in the biosphere, or in other words, it can appropriate more or less of the biosphere. This 'size' of the human economy is what Daly refers to as the scale of the economy. Furthermore, it is agreed that the larger the scale of the economy the greater the risk of destroying the conditions for human life on earth in the long run. The basic ethical challenge is thus to consider the interests of future generations.

This perspective differs from the focus on externalities in mainstream environmental economics. Externalities are usually conceptualised as exceptions to the rule – as disturbances in relation to the well-functioning markets. When the economy is considered to be a metabolic organism embedded in the biosphere, then all outputs from economic processes influence the inputs to future processes. 'Externalities' are thus pervasive and inevitable to such an extent that the concept loses its meaning. Of course, some economic processes are more harmful to the environment and human future than others, but the biophysical perspective also emphasises the importance of the sheer size of the economy.

When the scale of the economy has to be limited in the common interest of humanity, the question of distribution within the present generation comes to the fore. This question can be avoided more easily when it is possible to argue that the poor can be provided for through economic growth and so a redistribution is not necessary. However, if the economy has already reached or exceeded the maximum sustainable scale, the need for redistribution becomes pressing. Here ecological economics includes an ethical principle within the basic axioms of the programme: all human beings have the same right to be able to fulfill their basic needs, so it is not ethically defensible to appropriate so much of the biosphere that others are left without the possibilities of fulfilling basic needs. This formulation thus endorses the idea of basic needs – needs are not just a question of individual preferences which cannot be used as a basis for moral obligations (Max-Neef 1992). Some ecological economists will go further than this proposition and argue that all human beings have a right to an equal share of the biosphere (in practice this difference is not very important, as we are so far from fulfilling the most basic needs for everybody).

These basic ideas imply some fundamental research questions. First of all, the idea of the scale of the economy has to be operationalised: what is the present 'size' of the economy, and is this 'size' sustainable – and if sustainable, in which sense? This question has led to much fruitful research over the last 15-20 years. Not surprisingly, the research question and some of the answers more or less preceded the formulation of a research programme for ecological economics and thus constituted an important input into the formulation of the programme. The results comprise such concepts as the human appropriation of the product of photosynthesis (HANPP) (Haberl et al. 2007, 2008), ecological rucksack or hidden flows (Matthews et al. 2000), Material Input per Service Unit (MIPS) (Schmidt-Bleek 1993), ecological footprint (Wackernagel/Rees 1996), environmental space (Spangenberg 2002), different forms of energy accounting (Haberl 2001, 2002), industrial metabolism (Ayres/Simonis 1994; Ayres/Ayres 2002), and social metabolism (Fischer-Kowalski/Haberl 2007, Singh/Eisenmenger, this issue).

Secondly, the question of distribution has to be phrased in ecological terms. Thus some of the concepts mentioned above have been used to conceptualise, for instance, unequal exchange between nations in new terms, and new expressions have been coined to elucidate distributional aspects, such as ecological debt (Martinez-Alier 2002).

These efforts to 'calculate in nature' instead of calculating in money terms have been accompanied by a widespread awareness that there are no true answers to the questions raised – and that also the questions themselves are framed in terms that can be discussed. Even though the efforts to 'calculate in nature' can appear to be extreme expressions of philosophical realism, they have been accompanied by discussions on post-normal science, basic ignorance, etc. (Funtowicz/Ravetz 1991). Thus the limits to the scale of the human economy cannot be defined by natural sciences. Each science provides a selective (more or less narrow) perspective that must be supplemented with other perspectives, including some that highlight aspects not taken into account by the natural sciences in a given period of time (Wynne 1992, mainly discussed in relation to risk). Furthermore, there is a component of valuation in assessing limits, so that limits are a matter for negotiation as well.

Ecological economics includes the discipline of economics in the name. This implies that the research programme inherits the basic concern of that discipline: that is, the question of how different resources should be allocated to achieve specific social aims. As Daly (1992) argues in his seminal article on allocation, distribution and scale, ecological economics emphasises the importance of dealing with the scale issue instead of focusing only on allocation and distribution, although of course these issues have to be dealt with as well. The core question in relation to allocation concerns valuation: the resources should be allocated to the most valuable ends – and the ends should be achieved in the most cost-effective way. The main idea of ecological economics related to valuation is a basic theorem of incommensurability: essentially we have to choose between alternatives that are not comparable in any unambiguous way (Martinez-Alier et al. 2001). Values are not necessarily best represented through monetary prices, as prices result from the market with all its imperfections (power concentrations, political interventions, externalities), its historically and culturally determined wage structures, technologies, social institutions, distribution of income and wealth, etc. (Røpke 1999; Hornborg 2001, and also this publication). However, other alternatives to establish the values of different means and ends are not perfect either (values based on energy content, labour time, etc.). Therefore, we cannot escape from political decisions in relation to many issues of allocation.

The theorem of incommensurability leads to a number of research questions (O'Connor 2000). Firstly, different valuation parameters have to be developed. Which parameters should be included? Which parameters can be reduced to other parameters, and which cannot be reduced? Secondly, methods must be developed to improve the basis for decision-making in cases where several criteria have to be taken into account, that is, different kinds of multicriteria analysis. Thirdly, recognition of the political character of economic and environmental priorities implies a need for developing social institutions for democratic participation in decision-making. The study of value-articulating institutions has evolved considerably (Vatn 2005).

The formulations given above summarise the basic ideas regarding allocation, distribution and scale and the related research questions (it may be added that many ecological economists are aware of the interdependence between these aspects). This account of the research programme focuses on the conceptualisation of environmental problems, the ethical challenge related to these problems and the question of how to set priorities. In addition, the topic of the causation of environmental problems should be mentioned. Since the field of ecological economics has attracted many scholars with a socio-economic background (institutional and evolutionary economics etc.), it is widely held that the over-exploitation of the environment is rooted in basic features of the economic system – not in minor deviations from a fundamentally sound development (Røpke 2005; Paavola/Røpke 2008). Socio-economists argue that the human economy is embedded in a broader social and cultural framework that has to be included in analyses of the background of environmental problems (the idea of co-evolution) (Norgaard 1994; Jacobs 1996; Gowdy/Erickson 2005).

The socio-economic approach is critical towards the basic assumptions of welfare economics and tries to develop alternatives to conventional environmental and natural resource economics. Whereas welfare economics concentrates on short-term, static explanations of environmental problems in narrow economic terms, such as the lack of private property rights and market failures at a given point in time, the socio-economic perspective considers that environmental problems are constructed by irreversible and path-dependent historical processes where social, economic and cultural aspects are all relevant. Environmental problems thus require much wider institutional responses than establishing private property rights and 'setting the prices right' (elaborated in Paavola/Røpke 2008).

This broad, historically sensitive socio-economic approach is important for debates on the 'tragedy of the commons' (Hardin 1968) and on the conservation of biodiversity and natural resources more generally. In particular, the work of Ostrom (1990) has emphasised that it is 'open access' to resources that leads to their over-exploitation, not their common ownership. Since open access resources are owned by nobody, there is no incentive for anybody to restrain their use. While mainstream economists usually consider the establishment of private property rights to resources a solution, socio-economists emphasise that common property – under which the resource belongs to a community which maintains institutional arrangements for their ownership and management in order to avoid over-exploitation – is an alternative to both open access and private property (Gowdy 1994; Paavola 2007).

Many cases of over-exploitation have been the result of the privatisation of common property resources and may be referred to as 'tragedies of the enclosure' (Martinez-Alier 1991). Privatisation and the subsequent emergence of the market economy disrupts social patterns that have customarily emphasised social equity, and replaces them with wide social disparities. Extension of markets is particularly devastating to local biological resources because market decisions about these resources do not take into account the co-evolution of different species, the risk of destroying keystone species, the irreversibility of decisions, and the agents' fundamental lack of information. To prevent the loss of biodiversity, social control of markets is needed (Gowdy 1994).

Over-exploitation of resources also result from processes that take place far away from the actual resources. For instance, the dramatic growth in the consumption of apparel, electronics and toys since the late 1990s was encouraged by falling prices, reflecting the increased use of cheap labour in the global sweatshop. Social and political structures such as large-scale global inequalities and the American backing of authoritarian regimes are thus also decisive for environmental degradation (Schor 2005).

3. Links to the development debate

The process of decolonisation after World War II raised hopes that the newly independent countries would embark on a path of economic growth and development leading to prosperity. However, in many cases these hopes were frustrated, as new forms of domination emerged, and in some cases predatory states rather than developmental states were established (Castells 2000b). A critical stance towards these trends was formulated in the extensive literature on neo-colonialism, neo-imperialism and unequal exchange from the 1960s and especially the 1970s (see, for example, the works of Samir Amin, Arghiri Emmanuel, André Gunder Frank and Immanuel Wallerstein). This literature pointed out the transfer of natural resources from the developing countries to rich countries as an important issue and argued that this transfer could be interpreted as unequal exchange in terms of embodied labour time (Andersson 1976). However, in general environmental issues were not at the core and transfers were not conceptualised in terms derived from the physical sciences.

Some of those who took the first steps towards the establishment of ecological economics in the 1970s and 1980s had a background in critical development studies and, for them, it was an obvious choice to use the new ecological perspective to conceptualise unequal exchange in new ways, such as material and energy flows (Bunker 1985; Muradian/Martinez-Alier 2001; Giljum/Eisenmenger 2004; Eisenmenger et al. 2007; Singh/Eisenmenger, this issue) or in terms of the appropriation of land area (Andersson/Lindroth 2001; Hornborg 2001, 2006, and this issue). Concurrently with the economic exchange of goods and money, exchanges of embodied energy, appropriated land area, quantities of mobilised materials, etc., take place. Trade might also imply environmental load displacement, when polluting industries are moved to developing countries. Later on, when ecological economics became visible as a research field in the 1990s, the field attracted new scholars with a background in the critical studies of development and of capitalist crises, since it offered approaches that were in line with their perspectives.

The fields of ecological economics and political ecology can be seen as partly overlapping given their shared interest in ecological distribution conflicts (Guha/Martinez-Alier 1997; Martinez-Alier 2002; Paulson/Gezon 2005). These conflicts occur throughout the commodity chains – at the 'commodity frontiers' where energy and materials are extracted, in relation to water and land use as well as transport and waste disposal (including carbon dioxide emissions) – and many conflicts take place in developing countries. There are separate research networks on different types of conflicts, but as argued in a recent special section of Ecological Economics (Martinez-Alier et al. 2010), it is important to bridge these conflicts and apply a systemic perspective that integrates the study of social metabolism with sociological and political analysis and that highlights the link between the increase in social metabolism and the growing number of such conflicts.

Another link between the development debate and ecological economics is constituted by the issue of population. Ecological economics is strongly influenced by biological reasoning and thus considers humans not only in psychological, social and cultural terms, but also in biological terms as a species. The species perspective emphasises the enormous reach of humans – every corner of the earth is influenced by humans, and no other species has ever appropriated such a large part of the product of photosynthesis (Haberl et al. 2007, 2008). In socio-cultural terms this is apparent from the fact that humans have named every part of the world and established property rights for countries over all land areas. We are so used to conceiving the earth as the property of different groups of humans that just pointing out this phenomenon as an 'anomaly' in biological terms can appear surprising. From an ecological point of view, the enormous growth in the number of humans is risky, because the conditions of human life are endangered by the resulting increase in the scale of the human economy – in particular, when humans have a lifestyle commanding much more than 'the endosomatic energy consumption'.

Since the environmental agenda was first dealt with as an international issue at the UN conference in Stockholm in 1972, the population issue has been a subject of controversy between rich and poor countries. The rich blame the poor for the environmental effects of population growth, whereas the poor blame the rich for the effects of consumption growth. Ecological economists emphasise both problems and reject both the use of the population issue as an excuse for avoiding responsibility on the part of the rich countries and the playing down of the population issue by some social scientists, who only accept high consumption as a serious pressure on the environment. From an ecological point of view a high population density is problematic, no matter whether it occurs in rich or poor countries (this is not meant as an argument against cities, if other areas remain with low population densities), and the population issue can also be relevant for countries that have passed the phase of demographic transition.

Essentially, the introduction of an ecological perspective in relation to the development debate implies that the problems we face are even deeper than they were considered to be in the traditional exploitation approach. Material and energy flow studies reveal that contemporary human society is increasingly dependent on geological stocks for its material and energy needs. On a global scale, each person presently consumes about 9 tonnes of materials each year. Of this, the share of biomass is less than a third and the rest are construction materials, minerals, metals and fossil fuels. This is a significant shift from the 1900s, when an average global citizen consumed about 4 tonnes per year, and the share of biomass was more than three-quarters (Krausmann et al. 2009). Here, the concern with respect to sustainability is two-fold: resource scarcity on the input side, since geological reserves are limited, as well as on the output side, as most of these materials after their use eventually end up in the biological system where they cannot effectively be absorbed by nature, leading to pollution problems. Moreover, country studies reveal a high discrepancy of material and energy use between industrialised and developing countries, and thus the challenge related to distribution becomes ever more important.

Although the fight over resources is of paramount interest, the importance of including an ecological perspective in the analysis of global economic and social change is still not generally accepted within sociological and economic studies. A striking example is provided by Castells' monumental and exceptionally well-informed work on The Information Age (Castells 1997, 2000a, 2000b), which includes the environmental movement, but not environmental issues.

4. The persuasive potential of the ecological economic perspective

The reasoning of ecological economics in relation to the challenge we face can be summarised as follows:

- The human species has spread so much and appropriates so many resources that it is threatening the conditions that sustain its own life.
- The industrial economy is largely based on fossil fuels and materials from geological reserves leading to sustainability problems both in terms of resource scarcity and pollution, and readjustment will be very demanding.
- The rich are essentially maintaining their high standard of living at the expense of the poor.
- The ethical challenge regarding both future generations and the poor in the present generation is immense.

This way of formulating the challenge can be and often is rejected by several different arguments. The first one relates to the description of the problems. As illustrated by the Lomborg debate (Lomborg 2001) and by the publications from a number of American think tanks (McCright/Dunlap 2003; Dunlap/McCright 2010), some argue that environmental problems are grossly exaggerated and that environmental and resource limits are not relevant for any foreseeable future. This view is often closely related to the argument that we can trust technological change: technological change can be expected to solve specific problems if they occur, so there is no reason to be modest with regard to economic growth and consumption. Within ecological economics, these arguments have been widely contradicted in relation to the prolonged controversy on economic growth and the environment.

Others accept that humans face serious challenges, but apply an openly cynical perspective: In this world of limited resources, environmental threats, overpopulation, etc., we are engaged in a fight for survival. The challenge is to save oneself, not to make sacrifices to save others. The rich cannot and should not take on a responsibility for the poor (Hardin 1974). Sometimes this argument is based on biological reasoning: As with other species, humans are subjected to the 'law' of the survival of the fittest, and it does not make sense to ignore this basic condition. Another way of legitimating cynicism within the framework of social theories is to argue that the poor have only themselves to blame for their destitution – they could simply make an effort to change their situation (as Galbraith (1992) says, there is always an abundant supply of legitimating theories). This way of thinking is characterised by Sachs (1999) as the fortress perspective – the view that the rich should build their territories into fortresses to defend themselves against the hordes of the poor. Within ecological economics, this cynical approach is not accepted.

A very real worry concerns the question of whether humans are able to tackle these problems in time. The resilience of several ecosystems has already been endangered and important life-supporting mechanisms are threatened to such an extent that they may not be restored. Are we really able to change direction? It is difficult to cope with deep environmental and distributional problems, partly because the social and economic structures and related mechanisms preserve the unequal power relations, partly because of the extreme complexity of social systems. So many aspects impede a process that could reduce the human impact on the environment and improve living conditions for the poor at the same time: predatory states, the criminal economy (the huge size of which is described in Castells 2000b), the short-sightedness of politicians seeking re-election, the commercial interests of the media, etc. The challenges seem overwhelming, but there is no other option than to try, and persuading as many as possible to contribute to the process is decisive.

Ecological economics formulates the challenge we face, but can the field also provide the necessary persuasive power to encourage actions to be taken? As the discussion of critical arguments in relation to the perspective illustrates, the challenge is not generally accepted and thus persuasion is needed to achieve political backing for taking action to address this.

Ecological economists are generally aware that academic research is not simply about achieving a deeper understanding of different phenomena. This understanding is always achieved within the framework of some preanalytic vision and more specific theoretical assumptions regarding the object under study. When researchers' visions or assumptions differ, they will come up with different interpretations and ultimately with different political recommendations. However, some ecological economists, especially those with a natural science background, still find it difficult to give up a consensus perspective in relation to their research: when something is demonstrated to be rational then it should be possible to agree on the necessary action. This view underestimates the importance of both vested interests and ideology.

On the other hand, it is not simply the case that interests dictate understandings and attitudes. As Weale (1992: 58f) emphasises in his book on environmental regulation, interests have to be conceived – they cannot just be deduced from the social structures. He thus uses the concept of belief systems, stressing that such systems are not necessarily rationalisations of interests, but can also be logically prior to interests. The conceptualisation of social and economic structures as well as environmental conditions shapes how one perceives one's own interest. A topical example could be taken from the so-called 'war on terror': the rich and powerful may not be interested in sharing their riches with others and in adopting a less humiliating stance towards other cultures, but if they are persuaded to believe that a more equal distribution, better prospects for the poor and a more respectful relationship would reduce the basis for terrorism, they might find it in their own best interests to take steps in that direction. This example also illustrates how difficult it can be for such beliefs to achieve a breakthrough, where they are at odds with another dominant belief system (or dominant ideology), e.g. the idea that terrorists will only understand the language of military power.

Academic research is a battlefield where belief systems take shape. Concurrent with the achievement of deeper insight into different phenomena within the framework of preanalytic visions and theoretical understandings we are providing worldviews, ways of conceptualising different problems in general terms and belief systems that can frame how interests are conceived. In this 'struggle for souls' the question is whether arguments really matter. Do arguments have any relevance when it comes to making a choice between different basic perspectives? Or will those who identify themselves with the fortress perspective simply be beyond the reach of ecological economic reasoning, because they have a fundamentally different way of thinking and/or because they want to safeguard their own narrow interests? It seems likely that many people will be out of reach for an ecological economic perspective, but others will have less fixed ideas and be open to revising their outlook.

A crucial question of this conflict concerns the relationship between 'the crisis of nature' and 'the crisis of justice', using the terms of Wolfgang Sachs (1999). It seems that dominant social forces are rather successful in separating the two issues. One example is the watering down of the sustainability concept: increasingly it has developed into a concept of anything that is good, with no priorities and no demands – sustainable growth will solve everything so that the rich will not have to give up anything to improve the living standards of the poor and preserve the environment at the same time. A more specific example is the concept of genuine savings. It is true that this concept can illustrate how some developing countries are losing their natural riches and gaining little in terms of man-made capital, but the measure also appears to show that many rich countries have a sustainable economy. The concept does not cover the point that this 'sustainability' might be achieved through transfers from and environmental load displacement to other countries and that it co-exists with a level of consumption that could never be generalised without jeopardising the global environment.

To counter such conceptualisations, it is crucial to suggest terms that capture how 'the crisis of nature' and 'the crisis of justice' interact. An obvious way of doing this is to apply ecological economic 'calculations in nature', illustrating how much 'nature' the consumption of the rich appropriates compared to the consumption of the poor and also illustrating the transfers of 'nature' that take place. It is important to supplement the traditional focus on the environmental impact of production with a focus on the environmental impact of consumption, as this is the only way to combine environmental and distributional aspects.

Considering a few of the concepts suggested by ecological economists, some observations can be made regarding the factors that influence a concept's success. First of all, to be convincing, a concept has to be illustrative. One of the most successful proposals in this regard has been the ecological footprint idea (Wackernagel/Rees 1996). It is easy to understand the importance of the appropriation of land area, and this understanding has been supported by illustrative drawings. This success contrasts with the difficulties that have met attempts to popularise the exergy concept that is more difficult both to understand and to illustrate.

The footprint concept has been successful in relation to education, public information, NGO activities, etc., but it has had less impact in relation to bureaucratic monitoring of the environment (see Schaffartzik, this issue). One reason might be that it is difficult to provide reasonably unambiguous data as the basis for the calculations and in addition, the transparency of the concept is weakened by the mixture of the calculation of direct land appropriation (e.g. in relation to food production, housing and infrastructure) and the assessment of 'virtual' land appropriation related to energy consumption (the area of land needed to absorb carbon dioxide emissions). This combination is probably one of the reasons why few national statistical offices have become involved in footprint calculations, which makes it difficult to obtain official recognition. A second condition for achieving success with regard to official impact might be that the concept can be operationalised by the use of data that encourage the participation of statistical offices.

The environmental space concept has had a related fate as a popular eye-opener, but has met with even less success in terms of official monitoring. The concept does not really provide a macro perspective, as each environmental problem is treated separately, but the focus on a few central issues has been informative. A core problem regarding practical application of the concept relates to determinating the 'space' for each of the problems considered – an obvious barrier for the interest of statistical offices.

The work concerned with the calculation of material flows has been more successful with regard to obtaining official recognition and plays an important role in biophysical accounting and environmental indicators of national economies (Matthews et al. 2000; Weisz et al. 2006). In this case, the statistical offices of several countries have become involved and the European Environment Agency has promoted the concept as a relevant component of monitoring the environmental situation. There are also ambiguities in the data behind the calculations of material flows but some of them can be isolated (the very complicated problems related to the so-called 'hidden flows') and others can be treated by means of established procedures used by the statistical offices. However, this approach would probably not have been proceeded with, had it not been supported by actors who knew how to lobby effectively within the system (e.g. the Wuppertal Institute, World Resources Institute, Institute of Social Ecology). Indeed, the ability to lobby in a relevant way can probably be included as a third condition for the success of a concept.

There is still a long way to go before these eye-opening concepts can have any real impact on politics and further studies are needed, not only to develop and apply the concepts, but also to consider the conditions that will ensure that they are successful in influencing political practice.

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Abstracts

The paper introduces the emerging field of ecological economics and evaluates its potential for addressing some of the concerns within development studies. It takes as its point of departure the study of the relationship between nature and society that emerged in the wake of the environmental discourse in the 1960s. In the first section, a new perspective in the study of the interaction between society and nature is briefly outlined. Thereafter, the field of ecological economics is discussed as a specific example of this new perspective, followed by its potential link to the development debate, in particular the combination of the environmental and distributional issues and the challenges therein. Finally, the paper reflects on the persuasive potential of ecological economics in relation to politics.

Dieser Beitrag führt in das entstehende Feld der ökologischen Ökonomie ein und bewertet deren Potential für die Bearbeitung unterschiedlicher Fragestellungen innerhalb der Entwicklungsforschung. Den Ausgangspunkt bilden Studien zum Verhältnis zwischen Natur und Gesellschaft, wie sie im Kontext des Umweltdiskurses der 1960er Jahre entstanden sind. Der erste Teil beleuchtet eine neue Perspektive im Hinblick auf die Konzeptionen dieses Verhältnisses. Anschließend wird das Feld der ökologischen Ökonomie als ein spezifisches Beispiel dieser neuen Zugangsweise diskutiert, gefolgt von Überlegungen hinsichtlich ihrer Anknüpfungs-

punkte für die Entwicklungsdebatte, mit besonderem Fokus auf die darin enthaltene Verbindung von Umwelt- und Verteilungsfragen sowie auf die Herausforderungen, die sich daraus ergeben. Abschließend wird das Potenzial von ökologischer Ökonomie für Politikprozesse reflektiert.

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Uneven Development as a Result of the Unequal Exchange of Time and Space: Some Conceptual Issues[1]

For almost three decades, I have attempted to understand the economic polarizations of global society in terms of asymmetric transfers of resources that are made invisible by the dominant ways of representing development, economic growth, and technological progress. The acknowledgement of such asymmetric transfers – referred to in this research as the 'thermodynamics of imperialism' or 'ecologically unequal exchange' (Hornborg 1992, 1998) – is fundamental to understanding not only development gaps, but the very phenomenon of 'technology' as a social redistribution of resources. In recent years, it has been encouraging to see an increasing number of researchers involved in defining and measuring different kinds of ecologically unequal exchange (cf. Jorgenson/Clark 2009), even if the implications of this work for a radical reconceptualization of 'technology' remain difficult for most to digest.

This paper continues to scrutinize the concept of unequal exchange, which is a cornerstone not only of Marxian social theory but also of much ecological and post-colonial critique of the notion of 'development'. Many social scientists, looking at the world around them, are intuitively convinced that there is such a thing as 'unequal exchange' but would admit to having a hard time defining it. The problem of 'unequal exchange' is a paradigmatically Marxian topic in that *our difficulties in conceptualizing it can be seen as part of the conditions for its existence*. Thus it cannot be understood other than through an analytically demanding combination of epistemological and ontological arguments that require at different steps in the analysis the approaches of both deconstruction and objectivism.

My previous attempts to conceptualize 'ecologically unequal exchange' (e.g., Hornborg 1992, 1998, 2001, 2009) have raised two related kinds of objections to which a response is detailed here. The first is that the very notion of 'unequal' exchange must imply some kind of value judgement, and the second is that it should refer to the specific definition applied by Arghiri Emmanuel (1972). The following section aims to demonstrate why the first objection must be deemed invalid, by arguing that if objectively quantifiable net transfers of resources can be shown to be conducive to uneven capital accumulation (or 'development'), a normative concept of 'value' or 'inequality' is not required in order to observe that uneven development is a result of unequal exchange. The second objection is addressed in section 2.

1. How to define 'unequal exchange' without recourse to a normative theory of value

Few mainstream economists today would recognize the notion of 'unequal exchange' as an acceptable category of economics, but tend to deal with the problem of global inequalities by referring to monopolies and 'imperfect information'. The economists' solution is to try to envisage conditions for completely 'free' trade and more perfect competition and information flows, but if after two centuries the supposedly equalizing doctrines of free market economics continue to remain a distant mirage, it should be incumbent on economists to devise more realistic strategies to achieve equality. Suffice it to say here that as long as exchange is conducted in terms of monetary exchange values, and prices are understood to reflect the rational or even benevolent logic of market forces, there is no way – other than under conditions of monopoly – that a market transaction can be classified as 'unequal'. A million dollars' worth of Swedish Volvos exchanged for a million dollars' worth of Venezuelan oil is *by definition* perfectly 'equal' in terms of exchange value, which is the only gauge that neoclassical economic theory is capable of applying. However profoundly we manage to deconstruct the phenomenon of money as a vacuous, semiotic delusion, aptly classified by Marx as a species of 'fetishism', the ideological and practical hegemony of exchange value, gauged in terms of market prices, remains more intact than ever. The foundations of modern economics were devised by and *for* British bankers and stock traders in the early 19th century, yet continue globally to pervade the lives and thoughts of dominator and dominated alike.

Initially influenced by the Physiocrats' conviction that land was the ultimate source of value (Gudeman 1986), David Ricardo later subscribed to a labor theory of value that also became fundamental to the ideas of Karl Marx. Marxian theory has from the very start struggled with the analytical problem of how to effectively challenge the mainstream trust in money and in the fairness of market logic. Marx suggested that the market price of labor did not do justice to its 'real' value. Although he and his followers would be the last to admit it, he thus offered what is arguably a *normative* theory of value in the sense that it defined 'value' not in terms of the actual, subjective valuations of market actors – as in the fundamentally descriptive, neoclassic notion of 'utility', reflected in prices – but in terms of an analytical construct (the labor theory of value) that itself proposed to define an *objective basis of value*. Rather than accepting 'value' as contingent on the aggregated and transient subjectivities of consumers, Marx's supremely justified struggle to uncover the material conditions of accumulation (and the obvious exploitation of the working class) thus led him to conceive an analytical oxymoron. Beyond the mystifying price tags on labor that we know as wages, he pursued an objective foundation of value. Following Ricardo, Marx believed that embodied labor value was systematically reflected in exchange value. But valuation is a subjective act, and to 'objectively' define value is (paradoxically) itself an act of valuation.

Although meant to serve a commendable political purpose in Marx' own time, this approach to 'value' must be rejected as analytically untenable. Marx realized that in order to challenge the market ideology legitimizing capital accumulation, e.g. by positing asymmetric transfers of 'surplus value', it would be necessary to acknowledge some other gauge than price, but unfortunately chose to conceive this other gauge in terms of 'value'. The mistake was to conceptualize material asymmetries in terms of a subjectivist terminology. The concept of 'value' is itself normative. I doubt that it will ever be possible to convince economists or market actors that academics have a better knowledge of the 'real' value of things than the majority of market actors themselves. So, what does this other gauge – labor – represent, if not value?

The answer may be easier to detect if we turn to another kind of normative theories of value, namely those that underneath the price tags recognize not primarily labor but more generally *energy*. There have been many proponents of such theories over the years, including the so-called Technocrats in the 1930s and, more recently, the ecologist Howard T. Odum (1988), the economist Robert Costanza (1980), and the sociologist Stephen Bunker (1985). Odum's notion of *eMergy* (or 'energy memory') echoes Marx in suggesting that the 'real' value of a commodity reflects the amount of energy that has been invested in its production. Like Marx, Odum used an ultimately normative theory of value to pursue a putatively *scientific* argument that exchange can be viewed as unequal in the sense that some social categories are not properly compensated (Odum/Arding 1991). Costanza (1980), on the other hand, traced empirical correlations between embodied energy and price, in effect offering a *descriptive* energy theory of value, without considering the possibility of unequal exchange resulting from discrepancies between prices/wages and energy 'value'.

What both 'labor' and 'energy' have in common is that they are measures of *productive potential*. They are literally the 'productive forces' of any production process. But, contrary to Marx and Odum, there is no specifiable relation between the amount of productive potential that has been invested in a commodity and the way it will be evaluated on the market. Rather than reduce economics to thermodynamics, our task should be to see how the two are related. We need to keep them analytically separate while showing how they are interfused in actual social processes.

We have no theoretical reason to posit a connection between the attractiveness of commodities and the volume of labor time (or any other biophysical metric) that has been invested in their production. The former is tantamount to 'value' (= exchange value = price), the latter one of several possible measures of embodied productive potential (also including e.g. energy, eco-productive land area, volume of materials, etc.), and there need not be any positive correlation between them. The so-called 'transformation problem' is thus a non-problem. 'Value' is what consumers desire. To claim that value is essentially a question of invested labor time (or energy, or land area, and so on) is itself a *valuation*, in other words, to confuse that which is to be explained with the theory purporting to explain it.

Rather than say that we as social or natural scientists have access to a more authentic measure of 'value' than the people who do the valuing, we here have reasons to agree with the mainstream economists that 'value' is defined by the cultural preferences of consumers. This agrees well with anthropological and sociological studies of the semiotics of consumption following the work of Jean Baudrillard (1972), Marshall Sahlins (1976), and Pierre Bourdieu (1984), who all argued that valuation occurs within the specific cultural logic subscribed to by some particular group of people. Theories of value should be *descriptive*, i.e., they should be based on the valuations that people actually make, not on what theorists claim to be an objective source of value. Normative theories of value make the mistake of inserting themselves on the same logical level as the phenomena they are to explain.

How, then, can we posit the occurrence of 'unequal exchange' without recourse to a normative theory of value? This can be done by analytically demonstrating that there is, in very general terms, a systematic relation between (a) flows of productive potential, (b) flows of 'utility' or exchange value (price), and (c) economic growth and the accumulation of capital. But this relationship is not usefully expressed as Marx or Odum would have it, that investment of labor or energy somehow translates into exchange value. Rather, there is a kind of *inverse* relation between productive potential and price that follows with logical necessity from the juxtaposition of the Second Law of Thermodynamics and the social institution of market exchange. We know that energy is not so much 'invested' as it is *dissipated* in a production process (Georgescu-Roegen 1971). Finished products must represent an increase in entropy compared to the resources from which they were produced, yet they must be priced higher. If we consider, longitudinally, the transformation of a given set of natural resources into an industrial product, Odum's measure of 'energy memory' must necessarily correlate positively with 'utility' or price, but objectively speaking, the amount of remaining available energy will be *negatively* correlated with price. As utility or price increases, there will be less of the original, available energy left. This means that industrial centers exporting high-utility commodities will automatically gain access to ever greater amounts of available energy from their hinterlands. The more energy they have dissipated today, the more 'new' energy they will be able to buy – and dissipate – tomorrow.

However, the logic of this argument has often escaped its critics (e.g., Brolin 2006: 262).

I was developing these ideas on the 'thermodynamics of imperialism' in the late 1980s (Hornborg 1989, 1992) without having yet encountered Stephen Bunker's (1985) important contribution on ecologically unequal exchange in Amazonia, which proved to contain several ideas which agreed with my approach, and some which seemed less useful (Hornborg 1998). Although most of the transfer of available energy to industrial sectors is dissipated in production, and a small share returned to their hinterlands in the form of industrial products and waste, a significant part of it is 'invested' in an expanding, industrial infrastructure, which through a self-reinforcing logic involving economies of scale (Bunker 1985) will tend to augment this process of accumulation and the unequal exchange of energy on which it is founded. This, of course, is a very different way of describing what the economists know as 'growth'. An intensification of industrial production will generally mean more competitive prices, expanding market shares, and rising profits for industrial sectors, which in turn means more purchasing power with which to appropriate even greater amounts of energy and other resources from peripheral sectors. An intensification of natural resource extraction, on the contrary, will ultimately lead to local resource exhaustion and ecological degradation, prompting investments to be shifted elsewhere and truncating cumulative economic expansion (ibid.).

Note again that although referring to Odum and Bunker, this account of unequal exchange is *not* tantamount to an energy theory of value, but rather the opposite. Like Marx, Odum, and Bunker argued, it is necessary to refer to another gauge than prices to assess the effects on 'development' of market exchange, but unlike their work this account avoids the pitfall of trying to objectively define value. In *not* offering an alternative theory of value, we not only avoid having to systematically contradict the valuations that people actually make, but are also free to suggest additional gauges of productive potential that could be used alongside energy and labor to illuminate processes of unequal exchange. A well-documented such metric, for instance, is the study of material flows and 'biophysical trade balances' (Fischer-Kowalski 1998; Pérez Rincón 2006; Weisz et al. 2006; Krausmann et al. 2009; Gierlinger 2010).

I have suggested that an additional such perspective, which integrates the concerns of Marxian and ecological economists, might be expressed as *the unequal exchange of time and space* (cf. Hornborg 2006), a formulation which conceives of 'time' and 'space' as human as well as productive resources. Human time can be saved as well as invested (as labor) in production, and the same goes for space (or land). When considered in relation to the fundamental rationale of most modern technology, this means that time and space can be redistributed in global society through unequal exchange. Most technology can be visualized as devices for 'saving' time or space: time by increasing velocity (e.g., railways, cars, airplanes) and space by intensifying the use of land (e.g., through high-rise buildings or modern agricultural machinery). What we seldom take into account is that this local 'saving' of time and space is made possible precisely by the expenditure or *loss* of time and space elsewhere in the global system. To give an early and fairly simple example, railways in the 1840s may have saved time – and accessed more space – for those who could afford to use them, but obviously at the expense of the underpaid labor time of vast armies of miners, loggers, steelworkers, and railway workers, as well as of the equally underpaid natural spaces where clear-cuts and strip mines were all that remained of the landscapes that had to be sacrificed in the name of technological progress.

The unequal exchange of time has to a large extent already been exposed by Marxian theory, notably in the work of Arghiri Emmanuel (1972) , who showed that low-wage countries have to export more products in exchange for a given volume of imports from high-wage countries than they would have needed to if the wage level had been uniform. Yet it is doubtful whether the Marxists themselves have fully grasped the implications of this analysis for our understanding of the very nature of modern technology. If machines from the very beginning of the Industrial Revolution can be visualized as devices for saving time *for some* at the expense of the time available to *others*, it would not make sense to view the 'development of the productive forces' as a cornucopia promising to emancipate the global proletariat.

If we add the more recent recognition, for example in the notion of 'ecological footprints' (Wackernagel/Rees 1996), that there is also an unequal exchange of *space*, such hopes of technological emancipation seem even more untenable. The Industrial Revolution was not so much an absolute emancipation from land constraints as the local accumulation of a capacity to export and redistribute such constraints in global society (cf. Wilkinson 1973; Pomeranz 2000). It did not dissolve (European) land constraints once and for all as much as it provided Europe with ways of appropriating the land resources of other continents (Hornborg 2006). What the 'post-development' world might teach us is that technological 'progress' or 'growth' may not be the cornucopia that Ricardo and Marx generally believed, but local expressions of a kind of global zero-sum game. And what this means in terms of our understanding of concrete technology as a thoroughly *social* construct is even harder to digest, because it means that a tangible piece of machinery like a tractor or railway engine would *simply not be feasible* were it not for the uneven ways in which human time and natural space are *priced* in global society (Hornborg 2001). The contemporary, social condition of 'time-space compression', identified by the Marxian geographer David Harvey (1989), relies on global processes of *time-space appropriation*. The high-tech sectors of global society presently celebrating their efficient use of time and space appear largely oblivious of the extent to which this 'efficiency' has been made possible by exploiting vast investments of human time and natural space historically and presently made elsewhere in the world-system. Although such connections are generally concealed from their sight by virtue of geography or the passing of time, 'developed' sectors owe as much to slavery and ecological devastation as to genius and entrepreneurship.

Finally, as I have recently suggested elsewhere, even the net transfers of embodied labor can be mathematically converted into embodied land, viz., by multiplying embodied man-years by the average ecological footprints for the relevant category of laborers (Hornborg 2009: 250-251). This illustrates how, in biophysical reality, the relations between Ricardo's three factors of production (land, labor, and capital) are quite different from how they are conceived in mainstream economic models. Rather than being mutually substitutable, the three factors are asymmetrically related, with land the ultimate source of both labor and capital. Capital, from the start, was generated in the appropriation of other people's land and other people's labor.

I should emphasize again that I have been using the notion of 'unequal exchange' not in the moral sense of not getting one's money's worth, but in the naturalistic or realist sense of an objectively asymmetric transfer of some biophysical quantity or metric (*not* usefully referred to as 'value') by which the productive capacity of one social group is augmented at the expense of that of another. My argument is that industrial capitalism is founded and dependent on such objective, net transfers of productive potential. It is thus not a moral argument at the level of analysis, but can of course *issue* in a moral argument when articulated with the observation that an asymmetric transfer (net import) of energy or embodied land to one region or social group is the basis of a self-reinforcing accumulation of technological superiority and power vis-á-vis other regions or social groups.

2. How to disentangle the concept of 'unequalexchange' from earlier scholasticism

The second objection to my earlier work is that it would be useful to restrict the concept of 'unequal exchange' to the specific way in which it was applied by Arghiri Emmanuel (1972), viz., as a result of international differences in the price of labor. This view is fundamental to two doctoral theses recently produced at my own department at Lund University (Brolin 2006; Nordlund 2010). I would thus like to take this opportunity to address some conceptual issues that should be central to development studies. However, my focus here on Brolin's and Nordlund's approaches to these issues serves only to illustrate the kinds of miscommunication that such matters frequently generate. Together, these two contributions raise a number of questions that will be recognized as pivotal concerns of development studies in general.

Whereas most contributors to the discussion tend to assume an inevitable connection between theories of 'value' and theories of 'unequal exchange', I continue to maintain that the two concepts should be kept analytically distinct (Hornborg 1998, 2001). Briefly, as argued in section 1, unequal exchange is *not* a normative category, whereas an objectivist notion of value (i.e., one not simply equated with price) *is*. Much of the confusion regarding 'value' is necessarily highlighted in the ambition to integrate a Marxian concern with the unequal exchange of labor, as in Emmanuel's (1972) calculations, with the ecological economists' concern with the unequal exchange of energy or embodied land. Like most Marxists – and although he momentarily pauses to acknowledge global Malthusian constraints – Emmanuel was a strong proponent of economic and technological growth. To bring Marxian and ecological economics together in a single theoretical framework thus necessarily requires transcending some major differences in fundamental assumptions.

As Brolin's (2006) detailed history of economic ideas shows, attempts to illuminate the operation of international exchange by defining sources of value can be traced through a series of paradigms ranging from mercantilists and Physiocrats to classical and neoclassical economists, Marxists, and ecological economists. With all due respect to the immense inputs of human time and intellectual energy invested in these deliberations over the centuries, it must be concluded, based on reading Brolin's thesis, that the scholastic obsession with a reified notion of value in the 18^{th}, 19^{th}, and 20^{th} centuries is reminiscent, both in terms of scholarly output and ideological significance, of medieval theology. As any exegesis, such reviews will demand spending inordinate efforts on unraveling the contradictions and inconsistencies of individual scholars. While the history of such scholastic debates can be revealing, they can contribute little to demystifying the glaring inequities and ecological devastation of the modern world.

Emmanuel (1972: xxxi) writes that the most fundamental question in his study is whether it is a certain category of countries, rather than a certain category of products, that tends to be victimized by unequal exchange, defined by himself as the exchange of "a larger amount of their national labor for a smaller amount of foreign labor." In apparent agreement with this account, and with most readers of Emmanuel's treatise in the forty years since it was published, Charles Bettelheim (1972: 272) writes that "one of the chief conclusions of this work is that increase in economic inequality between nations is rooted in 'unequal exchange' ", defined as "the idea that on the world market the poor nations are obliged to sell the product of a relatively large number of hours of labor in order to obtain in exchange from the rich nations the product of a smaller number of hours of labor." Nevertheless, Brolin (2006) suggests that Emmanuel's account of unequal exchange is not about exchanging more labor for less. If indeed most or even *all* (ibid.: 347) researchers in the field have committed the same mistake of interpreting Emmanuel's argument in terms of a 'net transfer' of labor (resulting from international wage differentials, also referred to as differences in factor costs), might not the problem be a certain lack of clarity in Emmanuel's analysis?

One reason why it seems inappropriate to concede the concept of 'unequal exchange' to Emmanuel's rather inaccessible definition is that the phenomenon of unequal exchange is much more general and inclusive than the specific structure of exchange that he identified between capitalist nations in the twentieth century. Unequal exchange in the sense of net transfers of resources has been fundamental to processes of accumulation in a wide variety of historical contexts, extending back in time at least to the earliest agrarian civilizations. Moreover, such processes of unequal exchange can be gauged in terms of several other biophysical metrics, in addition to labor. There seems no reason why scholars concerned with such processes should be compelled to abandon the simple and straightforward concept of 'unequal exchange' in favor of less appropriate and more cumbersome concepts (such as 'non-equivalent exchange'). It is thus encouraging to see the recent publication of a special issue of *International Journal of Comparative Sociology* devoted to 'ecologically unequal exchange' (Jorgenson/Clark 2009), and it would be unfortunate if scholastic disputes were to constrain some researchers explicitly committed to illuminating this theme in their attempts to provide contributions of modern relevance on this topic. By adopting Emmanuel's conceptual framework, a student of 'unequal exchange' will automatically become immersed in Marxist exegesis.

In his brief but concise *Conclusions*, Emmanuel (1972: 265) writes that unequal exchange is "one of the mechanisms whereby *value* is transferred from one group of countries to another" (italics added) and that "it enables the advanced countries to begin and regularly to give new impetus to that *unevenness of development* that sets in motion all the other mechanisms of exploitation and fully explains the way that wealth is distributed." He observes that economists "have been divided into objectivists and subjectivists, but unequal exchange is denied by both parties – by one party because for them exchange is always equal in a situation of equilibrium, and by the other because for them equal exchange does not exist" (ibid.). "On the basis of the classical and Marxist doctrine of labor *value*," Emmanuel advises underdeveloped countries to "seek means to keep for themselves and prevent from leaking abroad the excess surplus *value* that they extract from their own workers" (ibid.: 267; italics added). These quotations from his *Introduction* and *Conclusions* will suffice to make it abundantly clear that Emmanuel's definition of 'unequal exchange' *was* initially presented as based on the idea that wage differences between countries generated international net transfers of labor 'value'. In order to account for international wage differences, Emmanuel refers to the demands of national labor movements, in part rooted in divergent cultural and historical experiences (Emmanuel 1972: 126-127).

As argued in section 1 above and elsewhere (Hornborg 2006), to attribute significance to the unequal exchange of embodied labor time is *not* necessarily to subscribe to a labor theory of value. The same applies to the unequal exchange of other productive resources such as energy or embodied land. However, to thus analytically disentangle the concept of 'unequal exchange' from theories of 'value' (whether of labor or land) tends to create major confusion among theorists who are used to grounding the former in the latter. This is probably the main source of misunderstandings and disagreements on unequal exchange. Although this is evident in Brolin's (2006) study, it does provide a useful history of ideas relating to both 'value' and 'unequal exchange', from Cantillon and Quesnay through Smith, Ricardo, and Marx to Innis, Prebisch, Lewis, and Emmanuel, and finally Odum, Bunker, and Martinez-Alier (ibid.: 335-354). The study's objection to the idea that ecologically unequal exchange is relevant to understanding uneven development is largely based on Bairoch's (1993) conclusion that the 'developed West' had no need for extractive peripheries prior to 1955, a notion that I have dealt with elsewhere (Hornborg 2007: 20-21; Pomeranz 2000). Like Bairoch, Brolin dismisses the idea that net appropriation of natural resources had any significance for development or world-system positionality.

Carl Nordlund's (2010) study also reviews the history of the idea of ecologically unequal exchange, but as background to an empirical investigation, applying the tools of social network analysis, of actual international trade in fuels and agricultural commodities. The trade in these commodities is quantified in terms of exchange value (money prices) as well as biophysical metrics, viz. energy content for fuels and embodied land (ecological footprints) for agricultural products. Nordlund's point of departure is that "it is difficult to deny the existence of some kind of ecological unequal exchange" (ibid.: 15), that the contemporary world-system is "brutally unfair in terms of resource consumption" (ibid.: 18), and that "the gaps between the haves and the have-nots" have increased with the growth in international trade (ibid.: 152). His "core question" is whether "there is a relationship between structural positionality [in the world-system] and ecological unequal exchange" (ibid.: 18) and whether this is related to "global differences in factor costs (of natural resources)" (ibid.: 22), a phrasing of (ecologically) unequal exchange that is presented as more in line with Emmanuel's account than with those of more recent theorists. In Nordlund's words, while Emmanuel "examined the national price-differentials for labor (i.e. wages), this thesis looks at price-differentials of another factor of production: land (and natural resources)" (ibid.: 181). Although Nordlund's reasoning is generally clear and consistent and his methodology both innovative and sophisticated, his approach raises some conceptual issues that deserve to be discussed.

Nordlund (ibid.: 178) claims that recent theorists of ecologically unequal exchange "are not concerned with" factor costs and the "underlying mechanisms" leading to net transfers of biophysical resources between nations, and that my own and Bunker's contributions are "quite far away from the fundamental theoretical stanzas found in the dependency school and world-system analysis." However, 'factor cost differentials' is merely another way of talking about relative differences in the prices of land, labor, and capital, which I have consistently viewed as an obvious 'underlying mechanism' (but inseparable from political, cultural, and other aspects) behind unequal exchange and capital accumulation (Hornborg 1998, 2001, 2006, 2009). Rather than contrasting Emmanuel's concern with 'factor costs' against others' concern with 'net transfers', as if they were exclusive options (Nordlund 2010: 264-265), they are clearly two aspects of the same total social phenomenon of unequal exchange. Moreover, rather than attribute international wage differentials to the different cultural backgrounds of Britons, Spaniards, and French, as does Emmanuel (1972: 126-127), I have consistently been concerned with their relation to world-system positionality. This is certainly more fundamental to my argument over the years than a recent "hint" (Nordlund 2010: 175).

It has been proposed that I cannot explain “why” the periphery “chooses” to submit to ecologically unequal exchange benefitting the core (ibid.: 173-174), as if being exploited was ever a matter of choice. Apparently, my argument that the cultural evaluations of consumers are irrelevant to the physical reality of resource dissipation in economic processes (Georgescu-Roegen 1971) has mistakenly been interpreted as a dismissal of ‘utility’ as a driver of consumption. Such a conclusion confuses my dismissal of the role of ‘utility’ in a thermodynamic account of economic processes with my view of its role in actual economic behavior.

Finally, the suggestion that a calculation including flows of *information* “could very well tip the scales of the whole equation, resulting in thermodynamic unequal exchange in the very opposite direction to what is intuitively perceived” (Nordlund 2010: 174) would run counter to the idea, expressed by Bunker, myself, and other world-system analysts, that development in core areas is tantamount to an accumulation of complexity, to the detriment of increasingly impoverished peripheries. ‘Complexity’ and ‘impoverishment’ *are* measures of (high versus low) information. The notion of core areas as cornucopias, exporting net flows of information to their peripheries, seems very much in line with mainstream economic theory, following an ideological tradition succinctly expressed in Rudyard Kipling’s image of colonialism as the ‘White Man’s Burden’. We are reminded of Maurice Godelier’s (1986) observation that unequal exchange tends to present itself as reciprocity, or even charity.

Although Nordlund (2010: 19) appears to endorse my rejection of what Paul Ehrlich has called “crackpot rigor”, and although he momentarily expresses doubts about quantification (ibid.: 264), immersion in the technical complexities of social network analysis can lead to conclusions that are very far removed from the conviction that the contemporary world-system is ‘brutally unfair’. The suggestion (ibid.: 264) that studies of specific commodity flows are better at identifying ecologically unequal exchange than studies of national indicators of consumption, such as ecological footprints, risks isolating distinct commodity flows (fuels versus agricultural products) to the point of obscuring the occurrence of ecologically unequal exchange. Thus, for example, the huge imports of fuels to the United States are never related to its huge exports of agricultural products (measured in hectares), although it should be obvious that the latter are largely made possible by the former. Instead, these agricultural exports – and flows of agricultural commodities in general – are simply interpreted as an invalidation of Nordlund's version of the hypothesis of ecologically unequal exchange (ibid.: 273-277). The focus on specific commodity flows, and on the comparison of monetary and biophysical measures of these flows, may thus have obscured the total socio-ecological metabolism of which they are a part, including the conversion of imported fossil fuels into agricultural exports (see Singh and Eisenmenger, this issue, for an empirical illustration of ecological unequal exchange based on the social metabolism of nations). The complex relation between embodied energy and embodied land, which this example highlights, will be addressed in the third and final section. Let us just conclude that although both Brolin's (2006) and Nordlund's (2010) conclusions on ecologically unequal exchange are largely negative, their struggles have been instructive. To paraphrase Wallerstein (1995), we need to hold the tiller firm as we try to navigate between the Scylla of scholasticism and the Charybdis of methodological fetishism.

3. Conclusions: The historical contextuality of ecologically unequal exchange

This concluding section elaborates some recent reflections (Hornborg 2009) on the conceptual challenges raised by the idea of ecologically unequal exchange. From a comparative, historical perspective, it is obvious that different kinds of environmental load displacement (through trade) will accompany specific kinds of capital accumulation. We thus need to use different measures of ecologically unequal exchange for different historical and geographical contexts. What they all have in common is a concern with the factor of production referred to as 'land', a factor which, as Nordlund (2010) observes, has been largely neglected by mainstream economists over the past two centuries. Different kinds of environmental load displacement reflect the different kinds of technological infrastructures that are being accumulated, as well as the particular resource endowments offered by specific geographical circumstances. Thus, the concern with 'land' must include not only embodied, eco-productive hectares, but also embodied energy, materials, carbon dioxide emissions, environmental degradation, water, etc. (cf. Jorgenson/Clark 2009). Different factors will be crucial bottlenecks at different times and different places. For example, 19th century Europe was in great need of additional eco-productive hectares (Wilkinson 1973; Pomeranz 2000), but was more than self-sufficient in mineral energy (Bairoch 1993; Brolin 2006). Conversely, 21st century United States is in great need of imported energy, but is more than self-sufficient in agricultural land (Nordlund 2010). Against this background, it is completely logical that European colonial wars were fought over land, while contemporary American wars in the Middle East are being fought over oil. Biophysical trade balances indicate that Europe, the United States, and Japan all import significantly more materials than they export, while the converse applies to most South American countries. It is well known that per capita ecological footprints and 'carbon footprints' are similarly skewed in favor of developed nations. Taking all these different circumstances into account is difficult but necessary, if we wish to generate a coherent understanding of ecologically unequal exchange. If we are indeed convinced that the world-system is 'brutally unfair', our research questions and methodologies need to be grounded in a conceptual framework that will not be undermined by statistics that seem to invalidate a superficial, single-metric theory of unequal exchange.

Let us conclude with a final observation on the historical relation between energy and embodied land, arguably the two most likely metrics for studies of ecologically unequal exchange. Up until the Industrial Revolution, energy and land were one and the same, converging in the production of food for human labor and fodder for draught animals. For two centuries now, the age of fossil fuels has kept land requirements and energy requirements distinct from each other, making it possible for historians such as Bairoch (1993) to seriously propose that European expansion had no need for extractive peripheries (but cf. Hornborg 2006, 2007; Pomeranz 2000). During this period, ecologically unequal exchange has not always involved net transfers of energy, nor has it always involved net transfers of embodied land, but it has always involved net transfers of *one* of these resources. As we are currently contemplating that peak oil and climate change may prompt us to turn to 'agrofuels', we are in fact imagining a future where land requirements and energy requirements will once again coincide. Once again, it seems, it will be possible to calculate the costs of transport distances in terms of eco-productive space. What this might entail in terms of our total world view and global social metabolism is beyond the scope of this paper, but if we shall once again see competition over scarce land for food, fodder, fibres, and fuel, we may rest assured that the realities of 'ecologically unequal exchange' and 'environmental load displacement' will be recognized as very tangible conditions of human existence. In such a future, also, ecologically unequal exchange will again involve concerns with *both* energy *and* embodied land. In terms of economic theory for understanding the course of history, this would amount to the bankruptcy of both Ricardian and Marxian concepts of 'labor value' in favor of a cosmology more akin to pre-industrial Physiocracy.

Suffice it to observe, at this point, that if the United States were to import best-practice, Brazilian ethanol (disregarding here the extent to which this ethanol is in fact subsidized by fossil fuels) to replace its current net *imports* of fossil fuels, it would require approximately 187 million hectares of Brazilian sugarcane[2], which is more than seven times the agricultural area within the United States presently devoted to export production. The current land area in Brazil devoted to sugarcane ethanol is around 4 million hectares. The long-term implications of the global energy shifts we shall be witnessing over the next few decades may very well lead to the conclusion that much of what we have come to know as 'industrial' technology is feasible only when it requires less land area than the same work conducted by humans and draft animals. This has indeed been the case through two centuries of fossil fuel energy, but at the moment we have no reason to believe that this specific kind of rationality will extend beyond the fossil fuel era.

1 The first half of this paper in part overlaps with Hornborg (2003).

2 Kenneth Hermele, personal comment 2011.

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Abstracts

The acknowledgement of asymmetric transfers of material, biophysical resources such as energy, matter, embodied land, and embodied labor is fundamental to understanding not only development gaps, but the very phenomenon of 'technology' as a social redistribution of resources. This paper argues that to posit the occurrence of ecologically unequal exchange does not need to imply a value judgement, or being constrained by the approach to unequal exchange provided by Arghiri Emmanuel. During two centuries of fossil fuels, ecologically unequal exchange has not always involved net transfers of energy, nor has it always involved net transfers of embodied land, but it has always involved net transfers of one of these resources. In a future dominated by biofuels, ecologically unequal exchange will again involve concerns with both energy and embodied land. In terms of economic theory for understanding the course of history, this would amount to the bankruptcy of both Ricardian and Marxian concepts of 'labor value' in favor of a cosmology more akin to pre-industrial Physiocracy.

Die asymmetrischen Transfers von stofflich-biophysikalischen Ressourcen wie Energie und Material sowie die Inanspruchnahme von Land (*embodied land)* und Arbeit zur Kenntnis zu nehmen, ist eine zentrale Voraussetzung, um nicht nur Entwicklungsunterschiede zu verstehen, sondern insbesondere das Phänomen der Technologie als soziale Umverteilung von Ressourcen. Dieser Beitrag argumentiert, dass die Feststellung von ökologisch ungleichem Tausch weder auf Werturteilen basieren noch mit dem Ansatz von Arghiri Emmanuel zu ungleichem Tausch begründet werden muss. Während zweier Jahrhunderte der Nutzung fossiler Energieträger, implizierte ökologisch ungleicher Tausch nicht immer den Nettotransfer von Energie, auch nicht immer den Nettotransfer von *embodied land*, jedoch immer den Nettotransfer einer der beiden Ressourcen. In einer Zukunft, die durch Biotreibstoffe geprägt ist, wird ökologisch ungleicher Tausch sich erneut mit Fragen nach Energie und *embodied land* auseinandersetzen müssen. Im Hinblick auf ökonomische Theorien, welche den geschichtlichen Verlauf erklären, würde dies ein Scheitern von Arbeitswerttheorien – sei es nach Ricardo oder nach Marx – bedeuten, zugunsten einer Kosmologie nach dem Modell der vorindustriellen Physiokraten.

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How Unequal is International Trade? An Ecological Perspective Using Material Flow Accounting (MFA)

Founded by Immanuel Wallerstein, the 'world system' perspective offers a theoretical approach to discuss the origins, nature and consequences of western society that emerged after 1500 A.D. (Wallerstein 1974, 1980, 1989). Over the years, this approach has gone far beyond the founder's perspective to represent a range of theories and approaches which often compete with and contradict each other (Shannon 1996; Hall 1997). Some of the central debates around the world system perspective relate to what constitutes a 'world system' and how, where and when it originated. The discussion on the origins of capitalism is not far from this debate and remains a concern for some scholars, particularly those dealing with unequal exchange across scales (between worker-capitalist, city-hinterland, core-periphery, north-south world regions). In this paper, we take as our point of departure the notion of 'ecological' unequal exchange as debated within the world system theory. Next, we introduce the concept of 'social metabolism' and its operational tool Material Flow Accounting (MFA) as a way to quantify 'ecological' unequal exchange. The third and final part of the paper illustrates the strength of MFA in this respect using empirical data from developed and transition economies and explores its potential for development studies.

1. The notion of unequal exchange

A central concern of the world system perspective (as well as of early theories of imperialism and dependency theory) has been to explain the notion of 'unequal exchange' between socio-economic systems. Within neo-classical economics, however, the notion of 'unequal exchange' or 'unfair trade' is simply seen as illegitimate. The foundations of the current economic theory were laid down by David Ricardo (1817) some 200 years ago. Ricardo's major contribution was the 'theory of comparative advantage', which assumes that if two countries are engaged in international trade, each specialising in certain goods, both would stand to gain from the specialisation that entails lower costs (Krugman/Obstfeld 2000: 13). More than 100 years later, the development of the 'Heckscher-Ohlin Model' by two Swedish economists Eli Heckscher and Bertil Ohlin was another benchmark in neo-classical economics. According to this theory, comparative advantage is influenced by the interaction between nations' resources (or the relative abundance of factors of production such as land, capital and mineral resources) and the technology of production (which influences the relative intensity of production, ibid.: 66). In other words, a country exports those goods in which it is abundantly endowed (resources and given technology) and imports that which is scarce. Trade, in this sense, is assumed to generate welfare and leads to a win-win situation for the exporter as well as the importer. Driven by these assumptions, so-called developing nations are pressed hard to accept the 'trade-for-development' agenda proposed by the World Trade Organisation (WTO) and the World Bank. Supporters of this policy further emphasise that revenue earned from trade liberalisation would promote environmental sustainability by allowing governments to re-invest this money for a clean environment (Muradian/Martinez-Alier 2001: 282).

Needless to say, there are several objections to mainstream economic theories of international trade. Critics pointed out that relying on comparative advantage would mean, in some cases, remaining locked into a pattern of production that excludes gains in productivity from economies of scale (Martinez-Alier 2003). Furthermore, trade might not be beneficial to all trading partners, since the distribution of economic benefits as well as environmental goods has so far been largely unequal (cf. Muradian/Martinez-Alier 2001; Fischer-Kowalski/Amann 2001; Hornborg 2001; Giljum/Eisenmenger 2003). Shafer (1994) draws attention towards the limitations placed on nations concerning their exports by demonstrating that the historical choices of production technologies made by former colonial powers continue to impose political constraints on production technology today.

The environmental implications of this 'dead hand of the past' are that nations dependent upon agricultural exports and low-priced manufactured goods often have weak civil societies and states dominated by the elites of the exporting sector. Consequently, environmental movements in such countries are mostly non-existent and, coupled with weak state autonomy, are not able to break out of this resource exploitation habit, move towards higher value-added products (Bunker 1985; Roberts/Grimes 2002: 176) or internalise the externalities (e.g. destruction of nature during mining) in the price of exports (Martinez-Alier 2003).

In a general sense, Marxist tradition maintains that trade, even if voluntarily undertaken, can generate a "systematic deterioration of one party's resources, independence, and development potential" (Hornborg 2001: 38), the economics of which is discussed at length by Wolf (1982) in *Europe and the People Without History*. An issue that remains the subject of debate, however, concerns how to ground the notion of unequal exchange in all its complexity. It has been acknowledged even among economists – within the sub-discipline of ecological economics – that price is an inadequate measure for determining unequal exchange Martinez-Alier 1987: 13, 90-91, 128-143; Daniels/Moore 2002: 71-72). Prices are a cultural construct or their value socially negotiable. For example, the unit price per tonne of raw materials is much lower than that of the finished product even though the mass as well as energy content is much higher in the former than in the latter. As such, in this case, price and mass are negatively correlated (cf. Hornborg 2001: 14-15; Fischer-Kowalski/Amann 2001: 31-32).

For Marxist world system theorists such as Arghiri Emmanuel (1972), Ernest Mandel (1975) and Samir Amin (1976), the primary mechanism through which internal concepts of modes of production link to the external question of 'unequal exchange' is 'wage differentials' (Bunker 1985: 42). In other words, labour is seen as a commodity to be used and compensated in production for a profit in the market (ibid.: 44). For example, Emmanuel (1972) postulates a hypothesis that suggests the process of unequal exchange between the core and the periphery is rooted in the stark differences of wage labour. According to Emmanuel, the level of compensation for workers in the periphery and those of the core are not the same, despite similar outputs per worker. The core receives inexpensive goods from the periphery (due to the low wages paid to their workers), that would be much more expensive if manufactured in the core. In the same manner, the periphery purchases expensive, high-wage goods from the core, that would be much cheaper if produced in the periphery. In both ways the periphery stands to lose by (1) exporting the surplus value of their goods into the hands of the core capitalists, and (2) by paying more for the goods that they could have cheaply produced instead of importing them from the core (Shannon 1996: 34).

Stephen Bunker does not agree with Emmanuel (1972) that differential wages of labour alone account for unequal exchange (Bunker 1984: 1018). In his opinion, using labour as a standard value for unequal exchange ignores the inequalities arising from devaluing nature in the periphery, a phenomenon that existed long before the rise of wages and the expansion of consumer demand in the core (Bunker 1985: 45). Basing his arguments on his study in the Brazilian Amazon in the period from 1600 to 1980, Bunker analyses the causes of ecological degradation and economic underdevelopment of the region. Exchanging the term 'productive economies' and 'extractive economies' (Bunker 1984: 1018) for 'core' and 'periphery' respectively, he argues that with the rapid growth in industrial production, there was a net increase in the demand for raw material. To meet this demand, a search for stores of raw materials drove the colonisation of new areas. Thereafter, these newly colonised areas served to supply raw materials to the industrial centres of the core, resulting in unbalanced flows of energy and matter from extractive peripheries to productive cores. Furthermore, there was a lack of local political power in the peripheries to prevent such unequal exchange (ibid.).

According to the logic of capitalism, the standard of value is in *labour* and not in the *raw material* as such (Bunker 1984: 1052). Contrary to this, Bunker maintains that the fundamental value of these natural products (such as minerals, oil, timber) is in the goods themselves rather than in the labour incorporated in them. The important point, however, is that this added-value is generally realised in the industrial sector and not at the periphery. Hence, the extractive economies are deprived of the value of their exports of raw materials as they do not yet incorporate the commodity that is actually valued by the capitalists, that is, labour. The profit-maximising logic of extraction for trade leads to an over-exploitation of the natural environment in the periphery (ibid.: 1054). Therefore, according to Bunker, "analysis of energy flows between regions and of different uses of energy in different regional social formations provides a much fuller explanation of uneven development than any drawn from conventional economic models" (Bunker 1985: 47).

From the point of view of the Second Law of Thermodynamics, Hornborg (2001: 38) finds Bunker's argument rather confusing. Since production is a 'dissipative' process (Georgescu-Roegen 1971), where energy is continuously being lost, "the productive potential of a given set of resources *diminishes* as it is being converted into a product, that is, as its value or utility *increases*" (Hornborg 2001: 38, emphasis in original). In this sense, according to Hornborg, Bunker's argument is misleading when he says that "additional [energy] value is created when extracted materials are transformed by labor" (Bunker 1985: 45).

Hornborg's (2001) own theory of unequal exchange is grounded in the Second Law of Thermodynamics. His key argument is that machines or technologies are categories of fetishism that disguise the globalisation of unequal exchange and development, thus contributing to a more polarised world order. According to Hornborg, the science of technology is not simply a matter of applying rational thought to nature, but something that deals with the *management* of resources accumulated through unequal global exchange. Since technology "presupposes such accumulation", technological infrastructure in this sense is not merely "material" from nature, but something that embodies part "knowledge" and part "exchange" as well (ibid.: 11-12).

It is acknowledged that technological innovation presupposes accumulation (Hornborg 2001: 11) and even in the past, the industrial revolution in England was in large part fuelled by the surplus generated by unequal trade and exploitation of colonies (Wolf 1982: 265-295; Bunker 1985: 41). Technology merely reinforced these terms of trade that led to the creation of cities comprising enormous techno-industrial infrastructures. Production being a dissipative process (from a thermodynamics perspective), these industrial centres "must" be net importers of energy because, "like all other dissipative structures (such as biomass), their techno-industrial infrastructures require continuous inputs of energy in order to maintain their structure" (Hornborg 2001: 45). Again, if production is a dissipative process, then the "sum of products exported from an industrial centre must contain less 'exergy'[1] than the sum of its imports" (ibid.: 42). In this sense, the amount of exergy that is left in the final product is at its minimum but the price is at its maximum. Hence, Hornborg argues, exergy and price are negatively co-related.[2]

Nonetheless, the essence of Hornborg's argument remains that economic growth and technological development follow a logic in which "historically specific, sociocultural concepts and institutions interact with natural law (thermodynamics) in generating an inequitable world order" (ibid.: 87). While the application of the entropy law to explain unequal exchange between industrial centres and peripheries could hold great explanatory power, to some natural scientists it still remains an empirical question whether industrial centres import more exergy than they export, and exports always represent greater entropy than imports.[3] Although they agree that an unequal exchange may take place in an economic sense between industrial centres and peripheries, these scientists very much doubt that the application of the entropy principle can technically substantiate such a claim (ibid.). From a thermodynamic perspective, the 'inflows' must include economic imports (valued) plus those (unvalued) raw materials that have been extracted on domestic territory during the production process and can therefore not be equated with 'imports' in an economic sense. Likewise, 'outflows' must include, besides valued exported products, also wastes, residues, emissions, etc. discharged into the environment of the producing system. Therefore, findings may show that the exported commodities may well contain higher exergy (lower entropy) than imported commodities in the case of peripheries because most of the entropy increase may be in waste produced (ibid.).

However, a biophysical argument is likely to be of immense value to the world system perspective in understanding unequal exchange. In this case, the notion of (ecological) unequal exchange can be expanded to include (a) unaccounted, and thus uncompensated, local externalities, and (b) the unequal exchange of different production times, that is to say, between extracted products (such as minerals and fossil fuels) that can only, if ever, be replaced over a long time as compared to those products (such as services and manufactured goods) that are produced rather quickly (Martinez-Alier 2003).[4] In the following section we shall explore to what extent the concept of *social metabolism* can resolve this problem.

2. Social metabolism

It is widely accepted that existing environmental problems are anthropogenic, owing to the way humans interact with their natural environment. It has therefore been argued that to gain an understanding of contemporary environmental problems and 'sustainable development', insights into the interrelations between society and nature are essential (Fischer-Kowalski/Weisz 1999: 216).[5] Interest in the physical dimensions of the economy/society, including its interactions with nature over the last decades, subsequently inspired the development of the concept of 'social metabolism' or 'industrial metabolism' in a more narrow sense. The concept investigates the interrelations between society and nature and also provides a guiding theoretical framework for Material Flow Accounting (MFA) (Schandl et al. 2002: 9). The term 'industrial metabolism' was coined by Robert Ayres in 1989 to refer to "the set of physico-chemical transformations that convert raw materials (biomass, fuels, minerals, metals) into manufactured products and structures (i.e. goods) and wastes" (Ayres/Simonis 1994: xi). The subject has been a multidisciplinary effort involving scientists from physics, chemistry, engineering, economics and the life sciences and hence the term is understood commonly among scientists associated with studies in industrial ecology (Fischer-Kowalski 1998: 62). Previously, the focus of these studies was limited to industrial societies alone, since most environmental problems were clearly attributed to their economic activities. In recent years, the terms 'social metabolism' or 'socioeconomic metabolism', used interchangeably (Fischer-Kowalski 1997; Fischer-Kowalski/Haberl 1998) to refer to both industrial as well as non-industrial societies, have gained wide acceptance and a number of studies have been commissioned.[6]

'Metabolism' originated as a biological concept to describe the chemical conversion of material and energy by organisms to sustain reproduction (Purves et al. 1992: 113). The concept of metabolism has been *metaphorically* extended to the level of society, implying that societies – similar to organisms – organise material and energy flows with their natural environment: they extract primary resources and use them for food, machines, buildings, infrastructure, heating and many other products and finally return them, with more or less delay, in the form of wastes and emissions to their environments (Fischer-Kowalski/Haberl 1998: 574).

Socioeconomic metabolism can then be defined as a process of extraction of materials and energy, their transformation within the economic process (such as production, consumption and transportation) and eventual release into the environment as wastes and residues (Schandl et al. 2002). In the process of industrialisation, societies increasingly mobilised resources from beyond the (short-term) biogeochemical cycles, or the so-called non-renewable resources obtained from geological deposits such as fossil fuels, minerals and metals. Technological innovation helps to solve problems on the input side i.e. resource scarcity, with new innovative methods to enable further extraction of those non-renewable resources from the bowels of the earth, although only temporarily until the eventual exhaustion of these limited resources (Fischer-Kowalski/Haberl 1998).

In the meantime, however, problems occur on the output side. Problematic wastes, both quantitatively and qualitatively, interfere with the earth's natural waste absorption capacity. With the increase in the mobilisation of enormous quantities of materials from these sub-terrestrial sinks, anthropogenic interference in natural biogeochemical cycles becomes even more pronounced. The amount of carbon, sulphur, nitrogen and phosphorus mobilised by the societal metabolism of industrial societies now ranges from between five and several hundred percent of those mobilised by natural processes (Ayres/Simonis 1994). Besides local pollution, we now move more and more towards long-term environmental problems such as ozone depletion, the greenhouse effect, rise in sea-levels, etc. (Fischer-Kowalski/Haberl 1998: 575).

3. Materials Flow Accounting (and analysis)

Material and Energy Flow Accounting (MEFA) is the operating instrument for social metabolism. In this paper we shall focus only on material flows. Consistent with the *systems approach*, national (also termed 'economy-wide') Material Flow Accounting (MFA) is a physical accounting method that provides "an aggregate overview, in tonnes, of annual material inputs and outputs of an economy including inputs from the national environment and outputs to the environment and the physical amounts of imports and exports" (Eurostat 2001: 15). Material Flow Accounts are mostly applied to the national level; in the following we will therefore focus on this unit of analysis.[7] Based on a simple environment-economy model where the latter is embedded into the former, the economy/society is seen as an open system of matter and energy exchanges entering and leaving the system (Schandl et al. 2002: 6). In analogy to the First Law of Thermodynamics on the conservation of energy (i.e. matter or energy is neither created nor destroyed but only converted), a law of conservation of mass can be postulated for all processes where no nuclear reactions are occurring (Weisz et al. 2002). This material balance principle provides a logical basis for the physical accounting of the interrelationship between the economy and the environment together with a consistent as well as a comprehensive account of inputs, outputs and material accumulation (Eurostat 2001: 11).

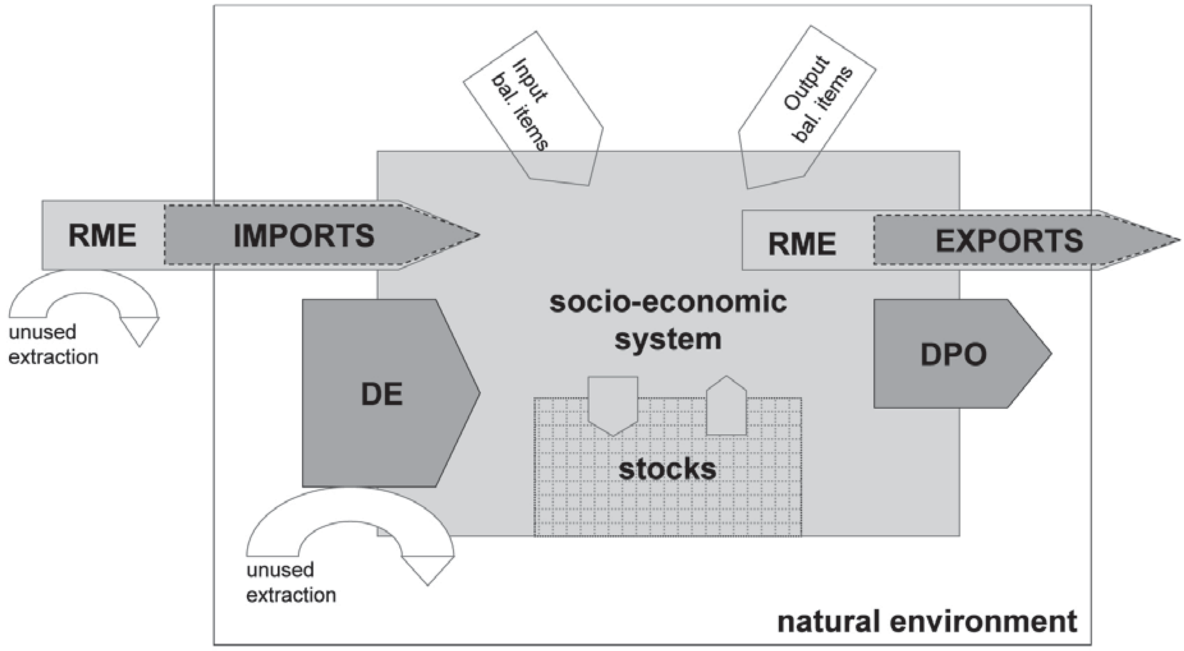


Figure 1: Schematic representation of economy-wide MFA
Source: Eurostat 2009, modified

Legend: DE = Domestic Extraction (materials extracted from the domestic environment that are used to create economic value), DPO = domestic processed output (wastes and emissions), RME = Raw Material Equivalents (upstream material requirements that were used in foreign economies to produce the traded good)

A decisive attribute of an economy-wide material flow account is its compatibility to the System of National Accounts (SNA) and integration into official statistics. Official statistics represent one of the most powerful means of societal self-observation, indispensable for setting policy agendas, defining policy targets and evaluating progress. Compatibility to SNA allows for the development of interlinked economic and environmental indicators, policy goals, scenarios, and intervention strategies. Environmental satellite accounts linked to national accounts covering inter alia "the stocks and use of the main natural resources, flows of materials and emissions" became part of the EU agenda in 1999 (Eurostat 2001: 9). In recent years, the sustainable use of resources has re-entered the political agenda (OECD 2004; Commission of the European Communities 2005; UNEP 2007) and environmental accounting with MFA as one sub-account was taken up in the statistical reporting routine in several countries and, for example, the EU.

However, the objective of MFA goes beyond mere physical book-keeping to deriving biophysical indicators that inform policy for reducing and/or regulating pressures on the environment as a result of economic activity. The need for indicators and indicator systems was adopted as Agenda 21 at the UN Conference on Environment and Development (UNCED) in Rio in 1992 in order to evaluate progress towards sustainability. As a consequence, in the years that followed, significant scientific research was directed towards developing sustainability indicators (Haberl/Schandl 1999: 178). The development of economy-wide Material Flow Accounting (MFA) was among prominent attempts in this direction (Weisz et al. 2001: 6).

A physical notion of an economy represents a striking departure from the traditional emphasis on monetary flows and exchange relations as in neoclassical economics. It provides clear evidence of the inadequacy or incompleteness of monetary measures of the parameters of the relationship between the human economy and its habitat (Martinez-Alier 1987: 13, 90-91, 128-143; Daniels/Moore 2002: 71-72). However, already in the late 1960s when it became culturally possible to take a critical stand on economic growth and related environmental problems, scientific studies on material and energy flows between societies (or economies) and the natural environment were taken up by some scientists. Pioneering work in this direction was carried out by Abel Wolman, who undertook a case study of a model U.S. city of a million inhabitants in 1965. He wrote: "The metabolic requirements of a city can be defined as the materials and commodities needed to sustain the city's inhabitants at home, at work, and at play […] The metabolic cycle is not completed until the wastes and residues of daily life have been removed and disposed of with a minimum of nuisance and hazard" (Wolman 1965: 179 in Fischer-Kowalski 1998: 70). Another prominent example is that of Boulding (1966), who views the present economy as an open system of material, energy and information exchanges (which he calls the "econosphere") in which there is a "total stock, i.e. the set of all objects, people, organizations and so on" that have inputs and outputs (1966: 5 in Fischer-Kowalski 1998: 70). Boulding's argument was to shift from the "cowboy economy" that attributed its success in maximising material to a "spaceman economy" where throughput is regarded as something to be minimised and in which the "essential measure of the success of the economy is not production and consumption at all, but the nature, extent, quality, and complexity of the total stock, including in this the state of the human bodies and minds" (ibid.).

In 1969, Robert Ayres and Allen Kneese presented a study – which in the 1990s was carried out as material flow analysis of national economies – for the United States between 1963 and 1965 as part of an attempt to re-conceptualise the economy, which apparently seemed to be subject to limitless growth, by placing this 'economy' within a thermodynamic framework (Fischer-Kowalski/Amann 2001: 11). Ayres and Kneese argued that "the common failure [of economics] […] may result from viewing the production and consumption processes in a manner that is somewhat at variance with the fundamental law of the conservation of mass" (Ayres/Kneese 1969: 283). As opposed to the message of Meadows et al. (1972) that economic growth would have to be stalled in order to remain within the earth's carrying capacity, the diagnosis of Ayres and Kneese was more subtle and acceptable to economists. In their opinion, it was not economic growth as such that mattered, but the growth in the material throughput of human societies that was significant. In other words, economic growth could continue if one could find ways to reduce the amount of material input (Fischer-Kowalski/Amann 2001: 11).[8]

Since the 1990s, national MFA has gained a strong scientific grounding (in particular within the fields of Ecological Economics and Industrial Ecology), and is gradually being integrated in systems of environmental headline indicators for national economies (e.g. EEA 2002; Eurostat 2010b; OECD 2010; UNEP 2007) and in statistical reporting through the implementation of environmental accounts (Eurostat 2010d; UN 2010). The large body of harmonised MFA studies was initiated by the EU-funded ConAccount project (1996–1997) and two international co-operations on material flow accounting under the leadership of the World Resources Institute (Adriaanse et al. 1997; Matthews et al. 2000). A major step towards methodological harmonisation was achieved by the publication of *Economy-wide material flow accounts and derived indicators: A methodological guide* (Eurostat 2001). A second round of methodological development and harmonisation occurred only recently with an EU/Eurostat initiative where an MFA time series for the EU-15 (Bringezu/Schütz 2001; Eurostat 2002) and later EU-27 (Eurostat 2010a) was established and a MFA compilation guide was published that gives guidance for the practical implementation of MFA (Eurostat 2009). The European Environmental Agency (EEA) published selected results from MFAs for the thirteen accession countries (Moll et al. 2002) and the OECD completed their programme on "material flows (MF) and resource productivity (RP)" with a four-volume report (OECD 2008a-d). Besides this, a number of National Statistical Offices included MFA in their reporting routine, such as Japan (NIES 2010), Austria (Statistics Austria 2010), Germany (DESTATIS 2010), and several other EU countries[9]. International comparisons of economy-wide MFAs were conducted for Austria, Germany, the Netherlands, Japan, and the USA coordinated by the WRI (Adriaaanse et al. 1997; Mathews et al. 2000), the EU (Bringezu/Schütz 2001; Eurostat 2002; Weisz et al. 2004) or for South American countries (Fischer-Kowalski/Amann 2001; Russi et al. 2008) and South American in comparison to Southeast Asian countries (Eisenmenger et al. 2007). Likewise, a number of economy-wide MFAs have been published in recent years by individual researchers.[10] MFA was also applied on the global level, leading to global MFA accounts for around 150 countries in the world for one year (Schandl/Eisenmenger 2006; Krausmann et al. 2008) as well as in time series (Behrens et al. 2007) and an aggregate global MFA account for the past 100 years (1900–2000) (Krausmann et al. 2009).

The MFA approach is promoted by the EU/EUROSTAT, the OECD and UNEP, several national statistic offices including Statistics Austria or the Japanese National Institute for Environmental Studies, scientific communities such as Ecological Economics and Industrial Ecology and international science programmes such as IHDP (International Human Dimensions Programme on Global Environmental Change) (Weisz et al. 2001: 6).

4. Common indicators derived from MFA

From economy-wide material flow accounts several indicators can be derived. The terminology for these indicators have already been widely used (see e.g., Adriannse et al. 1997; Matthews et al. 2000; Eurostat 2001, 2002, 2009), and they express the amounts actually used by a social system during the course of a year (metabolic rate), while the stocks represent the system size. In economy-wide MFA, the most widely used indicators are:

- Direct Material Input (DMI): Domestic extraction plus material imported
- Domestic Material Consumption (DMC): DMI minus exported materials
- Physical Trade Balance: imports minus exports[11]

Besides its use as an environmental indicator for "resource use" (Eurostat 2001: 9) for industrialised countries, the MFA approach has also served other purposes. A significant amount of research is devoted to gaining insights into the transitional processes towards industrialisation (Machado 2001; Castellano 2001; Krausmann et al. 2008; Schandl et al. 2008); to understanding the dynamics of socio-ecological transitions at micro-levels (Singh et al. 2001; Singh/Grünbühel 2003; Grünbühel et al. 2003; Ringhofer 2010; Fischer-Kowalski et al. 2010); to the possible delinking of material input with economic growth (Stern et al. 1996; Payer et al. 1997; De Bruyn/Opschoor 1997; Berkhout 1998); or to understanding north-south material flows (Muradian/Martinez-Alier 2001; Fischer-Kowalski/Amann 2001; Giljum/Eisenmenger 2003; Pérez Rincón 2006; Eisenmenger/Giljum 2007; Muradian/Giljum 2007; Eisenmenger et al. 2007; Eisenmenger 2008; Russi et al. 2008; Dittrich/Bringezu 2010), the last being important for the purpose of this paper.

5. De-materialisation of the economy and North-South flows

In the 1970s, environmental degradation was perceived to be inextricably linked to economic growth that had modelled itself on a "material-intensive approach of welfare" (Schandl et al. 1999: 31). The finiteness of the earth's resources was seen by some as one of the key limiting factors that argued against further economic growth if the environment were to be preserved (cf. Meadows et al. 1972). Stalling or even reducing economic growth represented a clear attack on the core mechanisms and beliefs of the modern economy. In contrast, the message of Ayres and Kneese (1969), who argued that economic growth could continue if one could find ways to reduce the material input, was more acceptable to economists (Fischer-Kowalski/Amann 2001: 11). Put differently, increases in income were not detrimental to the environment, rather it was the increases in material throughput that caused pressures upon the environment. In recent years, the environmental debate has changed considerably, from a mere 'growth critique' to finding ways to 'de-link' the economy from material use, in other words, with the goal being an economy that produces more economic output with less materials used. The idea was nourished by the example of the successful reduction of labour intensity (or productivity) for the production of commodities (Fischer-Kowalski/Amann 2001: 17). In the 1990s this idea resulted in the development of concepts such as 'factor 4' (Weizsäcker et al. 1997) or 'factor 10' (Schmidt-Bleek 1993). In recent years, resource productivity has re-entered the political agenda and has become a key notion in many political programmes on the sustainable use of resources. Examples are the EU Strategy on the sustainable use of resources (Commission of the European Communities 2005), the OECD programme on "material flows (MF) and resource productivity (RP)" (OECD 2004) and most recently the UNEP Resource Panel (UNEP 2007). However, the issue of delinking should not simply aim for the efficient use of resources but should strive for an 'absolute' reduction in the levels of resource consumption (Schandl et al. 1999), i.e. 'absolute delinking'. 'Relative delinking' on the other hand takes place when GDP is growing faster than material use; material throughput, however, continues to increase (Fischer-Kowalski/Amann 2001: 18). From empirical data we see that relative delinking is a rather common pattern for industrialised countries as soon as their economies reach a certain stage of maturation. Material use is then growing slower than economic output (see for example Fischer-Kowalski/Amann 2001; Eurostat 2002). However, examples for absolute delinking are still hard to find. In the years 1970–2005 we see absolute dematerialisation in the EU only in Germany, the UK and Sweden (Weisz et al. 2004) where the achievement is due to major structural change such as the closing-down of heavy industry. In countries that are still in the process of industrialisation, in particular countries experiencing fast economic development, material use is still growing in significant terms. We also find examples of the most unwanted development where material use is increasing faster than GDP. Examples for this pattern are resource-extracting and rapidly growing economies like Chile and Brazil, but also Portugal. Some examples of the different patterns of delinking are presented in figure 2.

However, Fischer-Kowalski and Amann (2001: 28) believe that, in part at least, the "reduction of material intensity in affluent countries is due to a process of externalising environmental impacts to the rest of the world, by means of an international division of labour in which most materially intensive processes of raw material extraction and industrial production are shifted to the less affluent countries in the South". Their argument is based on MFA studies of the six countries that report a steady increase in the amount of imports of raw materials and finished products that were previously manufactured domestically. Since the DMI only accounts for the weight of imports at the time of crossing the border, it does not reflect all the materials used and lost in the process of extraction and manufacture of the imported commodities. Let us now look at the import/export data of some affluent economies in relation to countries in transition.

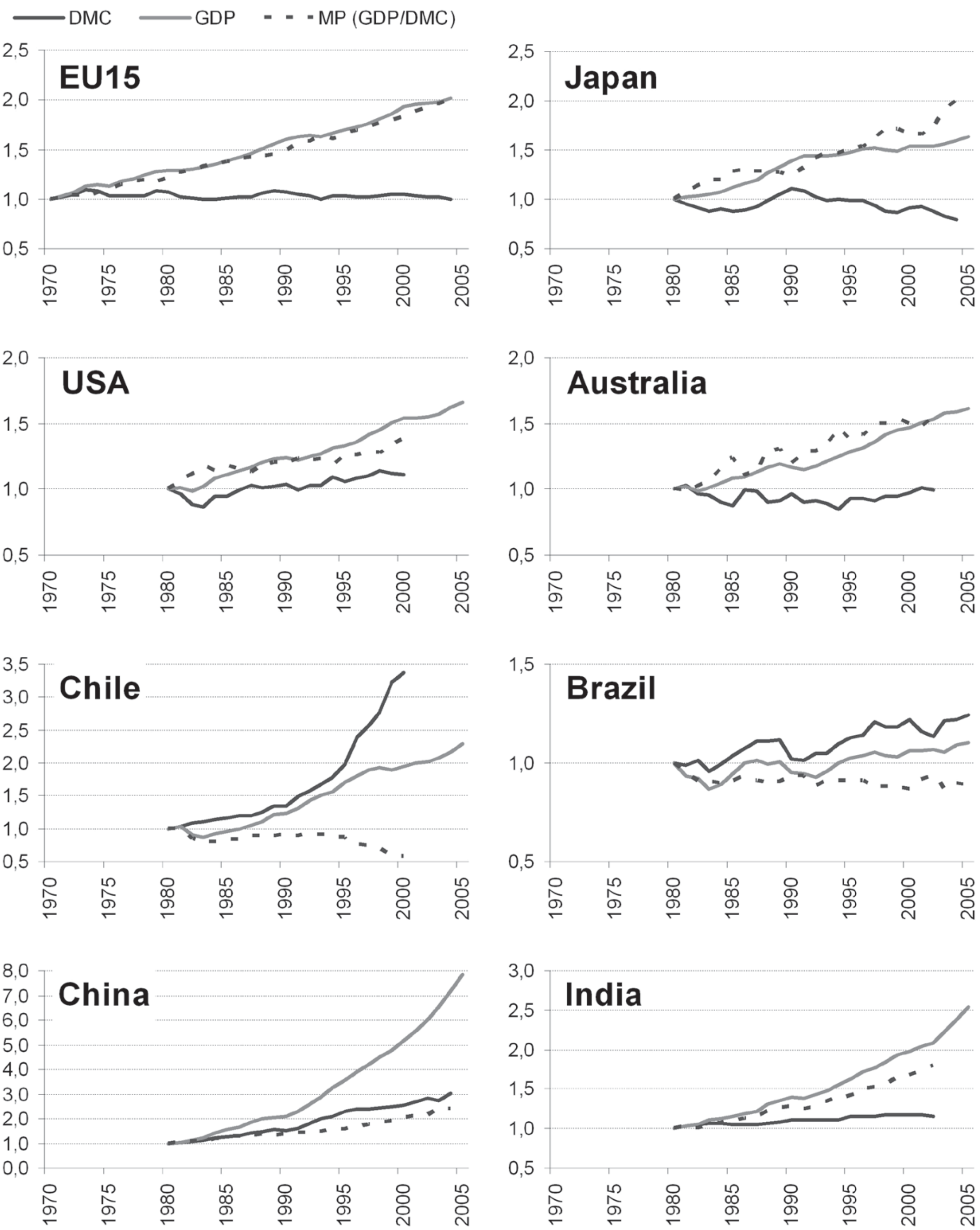
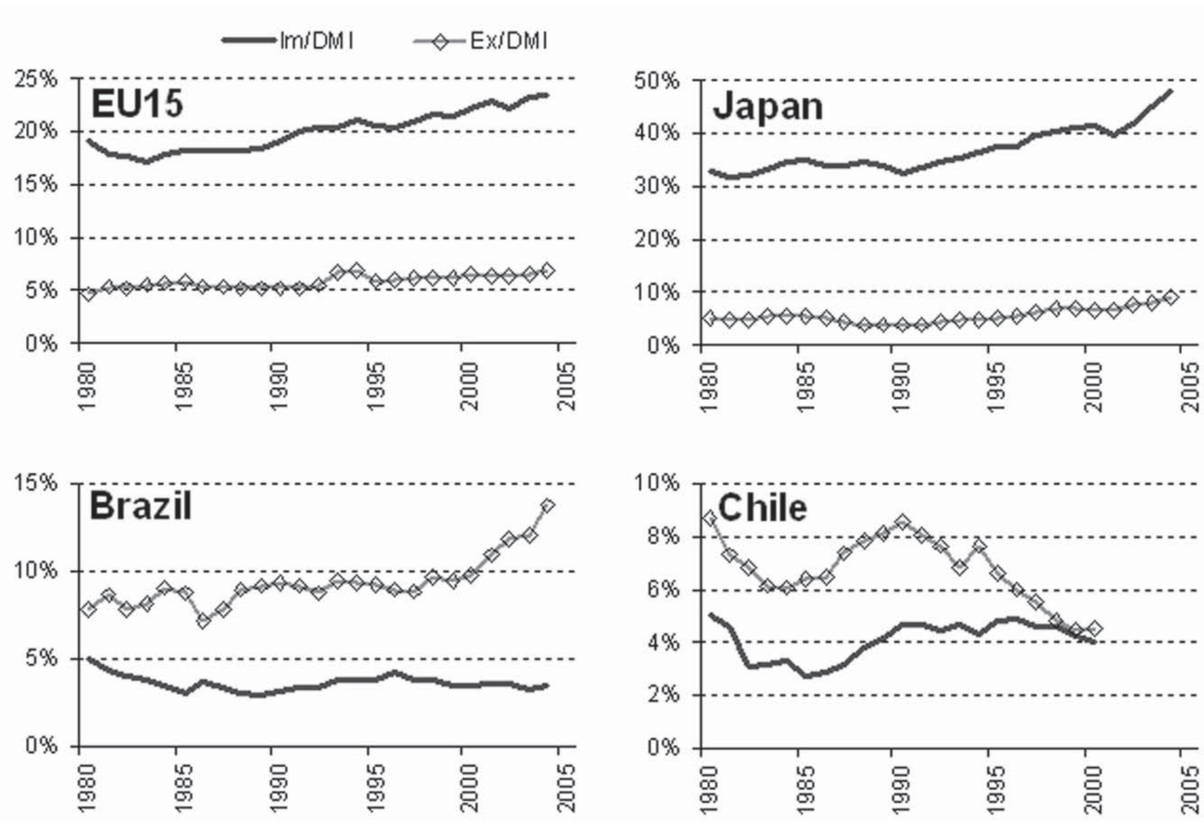


Figure 2: patterns of delinking: trends of material use (DMC), economic growth (GDP) and material productivity (MP) during the years 1970/80 to 2000/05
Sources: Chile: Giljum 2004; Japan: Ministry of the Environment 2007; other countries: Social Ecology Database 2010.

From figure 3, it is clear that industrial economies import significantly more than they export, resulting in a physical trade surplus[12], and many of these imports are basic commodities. On the other hand, industrialising countries are net exporters of natural resources. So far, studies in Brazil, Venezuela and Chile have reported a physical trade deficit (Giljum/Eisenmenger 2003). Fischer-Kowalski and Amann (2001: 29) suspect that the available MFA data are significantly indicative that developing countries have been suppliers of materially intensive processes and products for affluent economies throughout the last two decades. Schandl and Schulz (2002b: 26) interpret the UK's reduced level of material intensity to be a consequence of switching from material-intensive economic activities such as raw material extraction and processing to service-sector activities, while increasing their reliance on imported commodities to meet their material requirement.



A comparison of the relative weight of imports and exports (in % share of Direct Material Input, DMI)

Sources: Chile: Giljum 2004; Japan: Ministry of the Environment 2007; other countries: Social Ecology Database 2010.

In yet another study by Muradian and Martinez-Alier (2001: 182), the reliance of the North on non-renewable resources shows a significant increase between 1968 and 1996. Of the nineteen materials analysed, the authors found that imports of aluminium increased by a factor of seven; pig iron, iron and steel shapes, nickel (alloys) and petroleum products increased three to four times; natural gas, zinc and copper ores doubled; copper alloys and bauxite increased by 30%; tin alloys, lead, zinc ores, nickel ores, iron ores, lead ores, and crude petroleum remained more or less stable. Only tin ores and mineral fertilisers were reported to have declined as imports to the North.

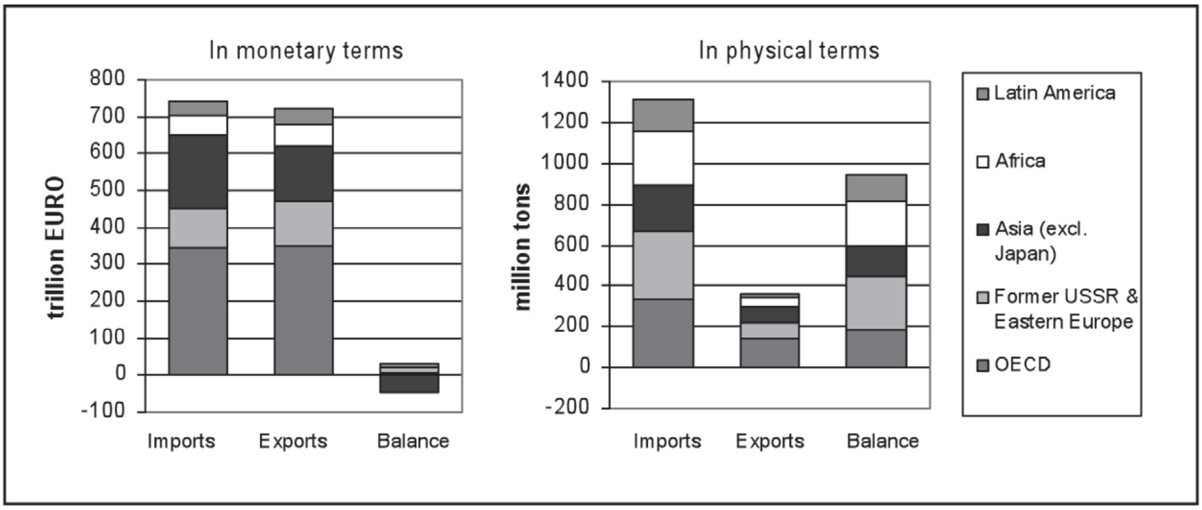


Figure 4: Monetary versus physical trade balance of EU-15, 1999
Source: Giljum/Hubacek 2001

Giljum and Hubacek (2001) have compared the trade balance of the European Union region (EU-15) in both physical and monetary terms. The picture that emerges is of a considerable physical trade surplus in the EU, but in terms of monetary units, this is more or less balanced (see figure 4). Of the total EU-15 imports, 60% are fossil fuels and 20% abiotic raw materials and semi-manufactured products, while exports are primarily crops and animal products to Africa, Asia, the former USSR and Eastern Europe (Giljum/Hubacek 2001).

However, the picture is not that simple. With the availability of MFA data for Asian countries, Eisenmenger et al. (2007) found that Southeast Asian countries have a positive physical trade balance, i.e. are net-importers of materials just as industrialised countries in Europe. They also do not export basic commodities like South American countries but export labour-intensive manufactured goods. From this it becomes obvious that there have to be other forces than economic development that underlie metabolic patterns. Eisenmenger et al. (2007), Krausmann et al (2008, 2009) and Eisenmenger (2008) identified population density as an important factor. Countries with a high population density are dependent on material inputs from other countries whereas countries with a low population density specialise in material extraction and export. This pattern holds true both for countries in transition and for industrialised nations. Examples of industrialised countries with a low population density which act as net-exporters to global markets are Canada or Australia (Eisenmenger 2008). figure 4 broadens the picture deduced from figure 3.

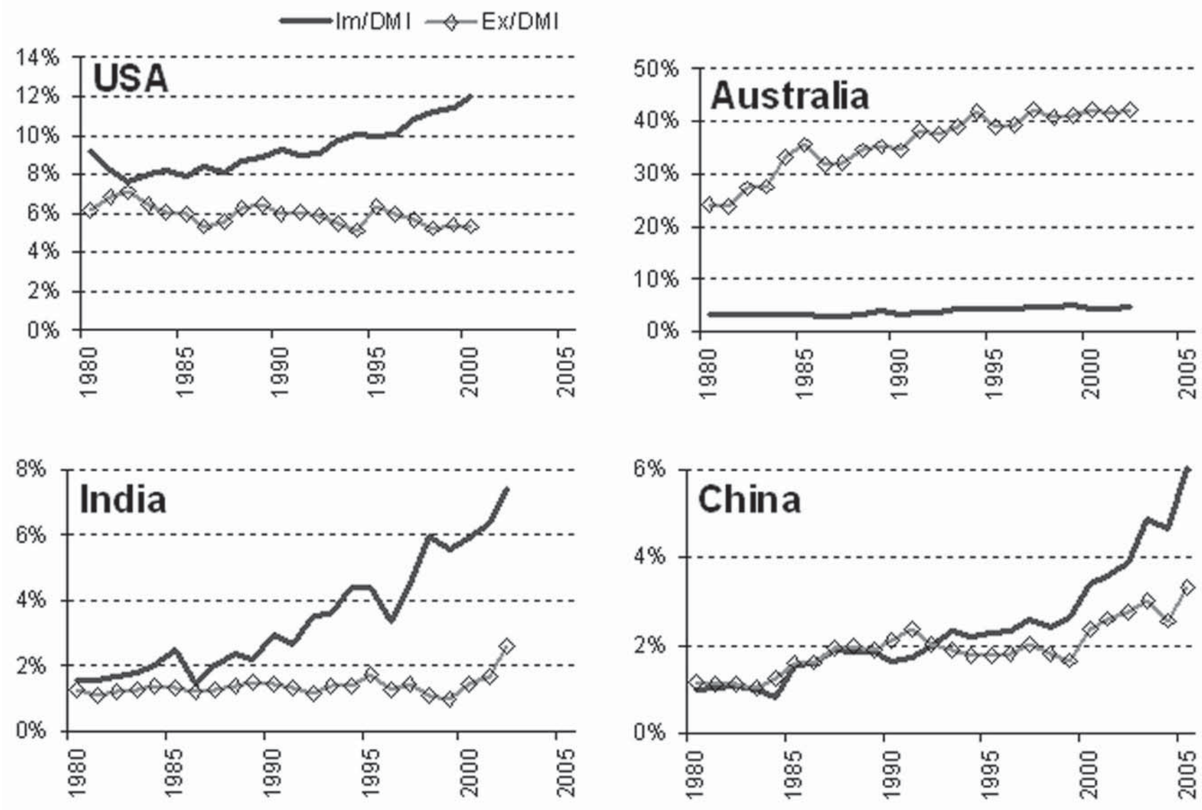


Figure 5: A comparison of the relative weight of imports and exports (in % share of Direct Material Input, DMI)

Source: Social Ecology Database 2010.

These findings add another perspective to the discussion on unequal trade: the periphery can no longer be considered exclusively as extracting economies that provide raw materials to the industrial core. This is true for sparsely populated countries like South America, but does not describe the metabolic profile of a densely populated country like China or India. Figure 5 additionally reveals the rapid integration of fast growing economies like China and India in global markets and the resulting increase of their trade dependence. With regard to industrialised countries, figure 5 shows that they do not always depend on the material input from global markets, as the examples of Canada or Australia demonstrate. However, the international division of labour and the assumed underlying pattern of exploitation still might still be valid if we consider other physical dimensions, for example, embodied labour.

6. Conclusions

Regardless of the debate as to whether capitalism is 500 years old or not, or whether surplus is generated by means of production or accumulation that is inherently unequal, or whether value lies largely in the labour or in the resource itself, the crucial point remains that there is a net flow of materials and resources from one place to another (from rural to the urban; from parts of the periphery to the core) to allow for surplus to accumulate. Production could not occur without resources being moved from their places of origin to the industrial centres where they are processed for added value, and surplus could not be generated without the exploitation of one by the other. Empirical studies based on the MFA approach presented above support the hypothesis postulated by the world system theory that unequal trade does exist between the affluent North (core) and countries of low population density of the industrialising South (periphery) in physical terms, which, presumably, would also be reflected in energetic terms as well. An international division of labour is established in which low population countries of the South are highly specialised in production in primary sectors of the economy (such as agriculture and mining) and exports from these sectors to the North. A further analogy is an unequal distribution of environmental burdens, such as the accumulation of hazardous wastes and/or emissions in countries specialised in metal mining and processing (Muradian et al. 2002). This pattern of the North exploiting the material resources of the periphery is true for countries of low population density. Countries in transition with a high population density do not appear as material-exporting countries. It can be expected, as some world system theorists would anticipate, that in these countries labour is being exploited instead of resources.

Trends in unequal exchange are starkly apparent even when DMI or DMC accounts only for the weight of imports as they arrive at the border. If we assume that the products that are being imported have already lost considerable weight during their manufacturing process, and that they have caused additional environment pressures in some way in the country of origin (e.g. overburden during extraction of the raw material), then the weight of the imported material is many times higher than it displays at the border (Eurostat 2002: 48). Hence, an import economy will reflect a DMI or DMC in its favour, while an export economy would be unjustly represented with high DMI and DMC levels (Weisz 2003). A physical trade balance which considers the raw material basis of traded goods, therefore, would need to account for these additional environmental burdens, which would involve converting the imported and exportable products into their Raw Material Equivalent (RME), that is, the used raw materials extracted from the environment from which the product is manufactured. In doing so, the depiction of unequal trade as it now appears would be further amplified.

Hence, from a general methodological point of view, MFA appears to be a useful tool to operationalise the notions of 'unequal trade' and 'accumulation' within the world system perspective. It seems certain that economic historians and sociologists have much to gain from analytical approaches that address the material realities of socio-ecological processes. Admittedly, much research for an acceptable synthesis still needs to be done, but it is equally essential to define the notion of unequal trade and to know what to measure in the first place. Once this is clear, the world system perspective stands to gain much from existing research and empirical studies based on material and energy flows analysis. The same is true the other way around. Accounting for flows of materials and energy across regions is not sufficient unless interpreted within the politico-economic context. Flows are purposely directed for the benefit of some and, as we have seen, to the loss of others. Economic as well as cultural patterns shape trade flows and thus drive material flows between countries and consequently also material extraction. The world system perspective offers insights into the historical as well as contemporary state of the world's political-economy that, if integrated, would provide explanations for international dependencies and would contribute towards a more holistic discussion on international material and energy flows. The significance of MFA can become more apparent if it serves as a tool not only for 'social metabolism' but also for the 'world system perspective'.

1 'Exergy' is that part of energy in a particular substance or context that is actually available for mechanical work. During the 1960s, exergy was defined as 'free energy' or 'available energy'.

2 'Emergy' on the other hand, is a short for 'energy memory'(Odum 1988). The final product, if valued in this way, would be evaluated to contain all the energy that has been invested into producing it, including labour. In this sense, the emergy of the final product is much higher than what it actually contains. For Hornborg (2001: 42) this would mean that emergy and price are positively co-related although in actuality the final product contains the least energy at the end of the process.

3 E.g. personal communication by Helga Weisz and Helmut Haberl, Vienna 2003.

4 Following the observation of Frederick Soddy, a pioneer of ecological economics, Martinez-Alier (2003) notes the antagonism between 'economic time' and 'geo-chemical-biological time'. The former proceeds according to the quick rhythm imposed by capital circulation and interest rates, and the latter is controlled by rhythms of nature. The triumph of economic time over ecological time by placing market values on new spaces has resulted in irreparable damage to nature and to local cultures which value their resources differently.

5 In the social sciences there is no real consensus on how a 'society' is conceived. Here, we define society as a "hybrid between the material and symbolic realms" (Fischer-Kowalski/Weisz 1999). In other words, society is not only a system of recursive communication (as in sociology) but also has a material basis that needs to be maintained and reproduced, such as its human population and man-made or cultural artefacts and infrastructure.

6 Two European Commission-funded projects were conducted in the Amazon region (Amazonia 21) and Southeast Asia (SEAtrans), the latter co-ordinated by IFF-Social Ecology. Their objectives were to gain insights into the transitional processes of these economies as they move towards industrialisation (Amann et al. 2002; www.seatrans.net). Further economy-wide MFAs were published for Chile (Giljum 2004), China (Xu/Zhang 2007; and for material inputs Chen/Qiao 2001), Mexico (Gonzalez-Mar-

tinez/Schandl 2008), and Ecuador (Vallejo 2010).

7 MFA accounts have also been conducted on the regional level (Schoder et al. 2005) as well as local level (Singh et al. 2001; Grünbühel et al. 2003; Ringhofer 2010).

8 However, in their most recent book Ayres and Warr (2009) argue that energy use is one of the production factors driving economic growth.

9 Czech Republic, Denmark, Finland, Hungary, Italy, Lithuania, Netherlands, Poland, Portugal, Romania, Slovenia, Sweden, UK, as well as Norway and Switzerland (Eurostat 2010c)

10 Among these, most noteworthy are a long-term time series – covering 150 years – for the United Kingdom (Schandl/Schulz 2002a), and other MFAs for industrialised countries such as Austria (Schandl et al. 2000), Finland (Mäenpaää/Juutinen 2001), and Italy (Femia 2000). National MFAs for transition economies are available for Chile (Giljum 2004), China (Chen/Qiao 2001; Xu/Zhang 2007), Poland (Mündl et al. 1999), Czech Republic (Scasny et al. 2003; Kovanda et al. 2010), Ecuador (Vallejo 2010), and Mexico (Gonzalez-Martinez/Schandl 2008)

11 The Physical Trade Balance is calculated inversely to the Monetary Trade Balance (= exports minus imports) and thus reflects the fact that physical flows move in the opposite direction to monetary flows. This means imports imply that money is flowing out of the importing economy, whereas physical mass is flowing into the economy.

12 Physical trade balance is achieved by subtracting exports from imports, in reverse of monetary trade balances. 'Deficit' in this context refers to the loss of biophysical resources (Eurostat 2001: 36).

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Abstracts

The paper contributes to the ongoing discussion of uneven development and unequal exchange within development studies. The point of departure is the world system theory that attributes uneven development to an inherently deficient world political and economic structure. In this paper, we propose the concept of 'social metabolism' and its operational tool, Material Flow Accounting (MFA) as a means to empirically illustrate the notion of 'ecological' unequal exchange by tracking flows of matter in international trade. Using examples from developed and developing economies, we show that there is a net flow of materials and resources from parts of the periphery to the core to allow for surplus to accumulate, both in monetary and biophysical terms. However, we also demonstrate that this pattern cannot be generalised for all periphery and core countries; other factors, such as population density and available land area, play an important role as well.

In der Entwicklungsdebatte gibt es eine laufende Diskussion über ungleiche Entwicklung und ungleichen Tausch, zu der dieser Artikel einen Beitrag leisten will. Der Ausgangspunkt ist die Weltsystemtheorie, die ungleiche Entwicklung als einen inhärenten Faktor der globalen politischen und ökonomischen Struktur sieht. In diesem Artikel schlagen wir nun vor, das Konzept des „gesellschaftlichen Metabolismus" und das daraus

abgeleitete Instrument der „Materialflussrechnung" zu verwenden, um den Begriff des ungleichen Tausches empirisch zu untersuchen. Anhand des Beispiels physischer Handelsflüsse aus entwickelten Ökonomien und sogenannten Entwicklungsländern zeigen wir, dass ein Nettofluss von Material und Ressourcen aus Teilen der Peripherie in die Zentren besteht. Dadurch wird die Akkumulation von monetärem und biophysischem Kapital in den Zentren ermöglicht. Wir zeigen aber auch, dass dieses Muster nicht für alle Länder der Peripherie und der Zentren gleichermaßen gilt. Andere Faktoren wie Bevölkerungsdichte und verfügbare Landfläche spielen ebenfalls eine wichtige Rolle.

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A Toe in America, a Heel in Asia? A Discussion of the Applicability of the Ecological Footprint to International Trade

1. Introduction

Development studies have long been preoccupied with the question of uneven development between the global North and South, the core and periphery, or industrialised and developing nations. As a means by which uneven development is created and reproduced, international trade has received much attention. Not as the sole driver of development, but as an important factor in the structural relations between regions, trade has been analysed within world systems theory. In contrast to the dominant paradigm in development studies of the late 1960s and building strongly on the work of those who were later grouped together as dependency theorists (most notably Prebisch 1950; Singer 1950), this school of thought argued that a linear procession from an 'undeveloped' to a 'developed' state would and could not occur universally because of the role which countries or regions play within the world system. These roles are mediated by trade, which enables regions to act as sources of raw materials or labour for other regions. Literature on the structural analysis of the world system and on the role of trade in uneven development abounds (Frank 1966; Wallerstein 1974, 1980, 1989; Emmanuel 1972; Mandel 1975; Amin 1976). Next to the Marxist interpretation of wage differentials as the major factor leading to unequal exchange, the notion of ecologically unequal exchange has been introduced and applied (Martinez-Alier/O'Connor 1996; Bunker/Ciccantell 1999; Giljum/Eisenmenger 2004). Here, the emphasis is on types of exchange which can be measured in biophysical units, such as trade in materials, energy, land and time. While the economic and social value of this exchange is highly variable and more than one valuation may exist simultaneously, their biophysical nature is less strongly contested. An acre of fertile land is of very different value – economically and socially – to a subsistence farmer than to a mining company, yet in terms of its biophysicality, it is an acre of land to both parties. Thus focussing on biophysical units leads to the omission of important information about the transfer that is actually being made, but at the same time, this focus allows for the quantification of net transfers of resources or capital accumulation, which are fundamental to development (Bunker 1985; Martinez-Alier 1987; Hornborg 2001). The lenses through which world systems theory and the concept of unequal exchange examine development create a landscape of focussed and blurry areas, even omitting important elements from the picture altogether. That the focus will be sharpest on a macro-scale is an advantage in analysing patterns of international trade, yet this will have to be combined with analyses at other levels of scale in order to move towards a fuller understanding of the dynamics of development and their relation to environmental factors.

One of the currently most prominent representations of societal pressures on the environment is the ecological footprint (EF) – it is cited by media, governmental and NGO campaigns alike as well as in different scientific communities when it comes to illustrating sustainability issues. Could the application of this concept to international trade then increase the awareness of and the depth of the analysis of ecological distribution conflicts? This paper outlines the ecological footprint approach and methodology in order to specifically examine its potential for quantifying ecological burden-shifting associated with trade and resulting ecological distribution conflicts. Trade as such could theoretically provide environmental benefits (e.g. by allowing for production where the associated environmental burden is smallest). However, with the laws of the capitalist market and not sustainability measures governing it, foreign trade principally leads to a draw on natural resources and interference in the regenerative capacities of ecosystems that extend far beyond the borders of the importing country or region. Next to the structural and/or systemic evidence which can be cited, a method for quantifying the redistribution of ecological burden which occurs through trade is needed. The ecological footprint proposes to translate human societies' demand for natural resources into a bioproductive area requirement expressed in global hectares. Bioproductive area refers to that area of land and water on which significant photosynthetic activity occurs. The area required can be compared to the locally or globally available bioproductive area in order to verify whether or not a given society is consuming natural resources within or beyond local or global limits. In communicating the draw of countries on biocapacity outside their borders through trade, the ecological footprint analysis is a powerful tool. At the same time, it does not permit straightforward conclusions to be made regarding the sustainability of these trade relations.

2. Pushing the limits

"If we continue with business as usual, by the early 2030s we will need two planets to keep up with humanity's demand for goods and services" (Hails et al. 2008: 3)

In light of the persistent lack of a second earth, this forecast in the introduction to the 2008 Living Planet Report (LPR) of what awaits us if we don't 'change course' is a gloomy one. Published every two years by the World Wildlife Fund, the LPR assesses the state of planet Earth. While the Living Planet Index as a measure of biodiversity is used to analyse the condition of the earth's ecosystems, the ecological footprint is the tool of choice in approximating 'humanity's demand' on the earth's resources.

Humanity – in the words of the LPR – or more specifically human societies are dependent on the earth's resources to meet their metabolic needs. Much as the human body requires food, water, air, and light and produces wastes and emissions in the process of using these resources (basic metabolism), human societies require inputs (e.g. biomass, water, minerals, fossil energy carriers) and generate outputs (wastes and emissions). This societal metabolism (Ayres/Kneese 1968; Adriaanse et al. 1997; Fischer-Kowalski et al. 1997; Matthews et al. 2000) exceeds the sum of the basic metabolism of the members of each society: infrastructure and production of goods and services add substantially to the total throughput. In determining a given society's impact on the environment, both the composition and the volume of its metabolism play a decisive role. A cross-country comparison shows that societal metabolism is highly variable, depending especially on the principal mode of subsistence and the economic structure of the country, with geographic location and resource endowment playing a vital role. In meeting resource demands, trade has an increasingly important function. In most industrialised countries, fossil fuel and metal ore in the form of raw materials and secondary products are imported to a large extent rather than extracted or produced domestically (Krausmann et al. 2008).

In the Living Planet Report, 'humanity's demand' on the earth's resources is differentiated by countries, which are presented in terms of their role as ecological 'debtor' and 'creditor' countries: In very general terms, debtor countries are those which consume more resources than are available within their borders while creditor countries are those which consume less than is available on their territory.

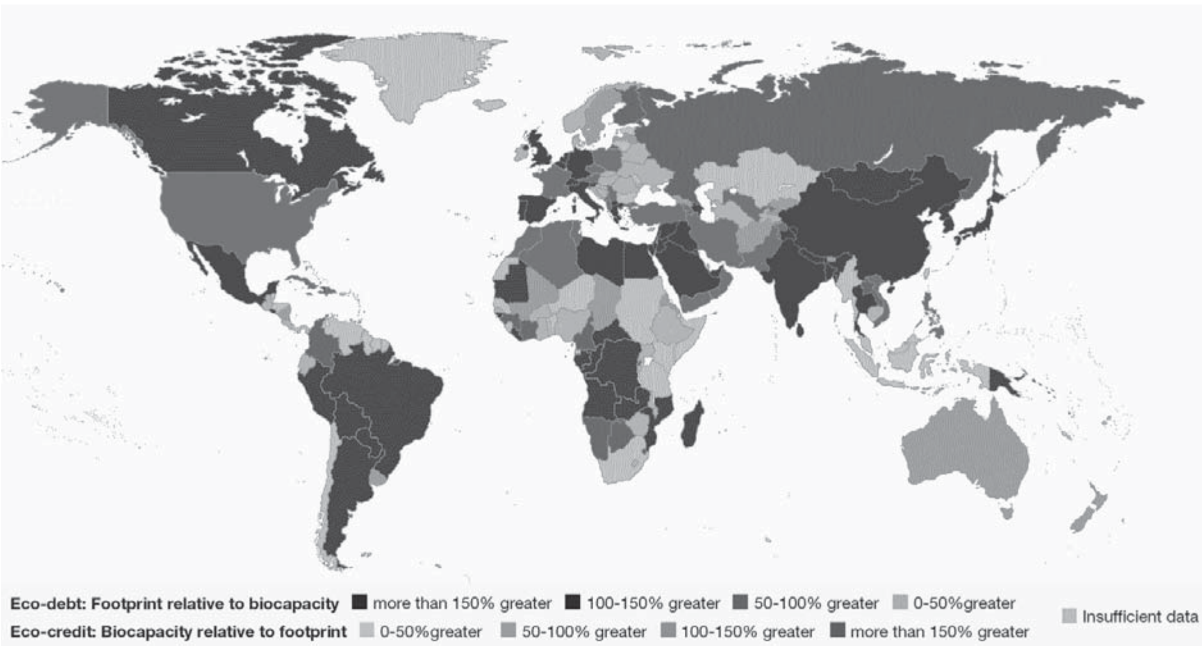

Figure 1: Ecological Debtors and Creditors of the World 2005
Source: adapted from Hails et al. 2008

In the framework of ecological footprint analysis, these results are obtained by comparing a country's ecological footprint to the bioproductive area, or biocapacity, available within that country. Resource use expressed as ecological footprint greatly exceeds available biocapacity in Spain and Italy or Libya and Egypt, for example. Other ecological debtors are Mexico and the USA, France and Germany, Morocco and Algeria or India and China. The ecological footprint lies significantly below biocapacity in much of South America, in Canada and parts of Middle and Southern Africa. Yet are these results already a good proxy measure for sustainability? How useful are they in assessing the role of trade? Does the shifting of environmental impacts through outsourcing production become visible using this approach?

In the following, a brief outline of the ecological footprint methodology will precede a more specific examination of how trade can be accounted for in EF analysis. The point of this assessment is to gauge the utility of the ecological footprint as a tool for quantifying ecological distribution conflicts.

3. What's in a footprint?

The ecological footprint is a very prominent and at the same time also highly contested indicator. The following section of the paper will be devoted to introducing the concept of the ecological footprint as it has been developed until now. The ecological footprint concept was developed in the early 1990s and originally introduced as *appropriated carrying capacity* (Rees 1992). The term *carrying capacity* was borrowed from the ecological discipline, where it is used to describe how many individuals of a given species can be permanently 'carried' or sustained by an ecosystem without causing irreparable damage to the functions and the productivity of that ecosystem (Odum 1983). Appropriated carrying capacity is then used to describe that part of this carrying capacity which is already claimed by human societies (Rees 1992). In the late 1990s, it was basically this concept that Wackernagel and Rees (1996) presented in more popular terms as ecological footprint analysis, "an accounting tool that enables us to estimate the resource consumption and waste assimilation requirements of a defined human population or economy in terms of a corresponding productive land area" (ibid.: 9).

The questions that ecological footprint analysis proposes to answer are: How much bioproductive land is required in order to sustain a given level of consumption - that is for the production of required resources as well as for the absorption of waste and emissions (Rees 2003)? How does this area compare to the *available* bioproductive area (Wackernagel et al. 2002)? This corresponds to the comparison of "human demands [...] with nature's available supply for human use" (Wackernagel et al. 1999: 317).

In the calculation of the ecological footprint, societal metabolism is translated into area units. This conversion can be quite intuitive for biomass-based raw materials and products (i.e. primary plant and animal biomass as well as secondary products such as non-synthetic textiles, wooden furniture, paper) on which the EF focuses: It reflects the (hypothetical) area required to grow them. Non-renewable materials such as fossil energy carriers, minerals and ores on the other hand, are included in the ecological footprint in terms of the built-up area as well as the energy requirements associated with extraction and production.

The ecological footprint is calculated for *apparent consumption*, i.e. for domestic extraction plus imports minus exports. This should allow for allocation of the ecological footprint to those socioeconomic systems generating the demand, i.e. where the final consumption occurs. The EF corresponding to the production of exported goods is accounted for within the total ecological footprint of the socioeconomic systems importing these goods. It is important to note that, in contrast to the monetary national accounts, the ecological footprint more or less follows a territorial principle. Its frame of reference is the apparent consumption within the territorial boundary of a system and not the apparent consumption generated by the residents of the system at hand (residence principle). This can best be illustrated using tourism as an example: By applying a territorial principle, the resources consumed by tourists are allocated to their travel destinations, i.e. to those countries in the borders of which the consumption occurs. Under the residence principle, this consumption of resources would be allocated to those countries of which the tourists are residents. International bunkering of fuel is another example in which it makes a difference whether a territorial or a residence principle is applied.

The ecological footprint distinguishes 5 land use categories which were developed by Wackernagel and Rees on the basis of the classification scheme of the International Union for the Conservation of Nature IUCN (Munro 1991): cropland, grazing land, forest, fishing grounds, and built-up land. These categories continue to be the ones commonly used in footprint studies (cf. Monfreda et al. 2004; Ewing et al. 2008). In most existing accounts, energy consumption is translated into forest area, sometimes denoted as carbon uptake land. The EF of energy use is usually calculated as the forest area which would be required to absorb the CO_2 emissions associated with the primary energy use of one year. The calculation is performed assuming an average global absorption rate for the forest (i.e. the measure of how many tons of carbon are absorbed by the forest per hectare and year) (Wackernagel 1999a; Monfreda et al. 2004; Kitzes et al. 2009). Carbon uptake land differs substantially from other land use types in the ecological footprint in that it has no real 'counterpart': While wheat is indeed harvested from crop land and livestock does feed off grazing land, it is not current practice to plant or preserve enough forest to offset greenhouse gas emissions. For most industrialised countries, carbon uptake land makes up the largest share in their ecological footprint. Aside from built-up land, the data for which comes from actual land cover statistics, all other categories in the ecological footprint must be understood as the translation of material flows into the hypothetical land area required to sustain them.

The unit of this hypothetical land area is the global hectare (gha), which allows for the comparability of EFs across nations and with the global footprint. This unit conversion is necessary because one hectare is simply not the same as the next in terms of biological productivity: One hectare of Austrian forest, for example, has an annual productivity of 6.16 m^3 harvested wood. The corresponding value for neighbouring Hungary is only about half as high at 2.90 m^3/ha (Global Footprint Network 2006). Direct comparison of the area required in Austria or Hungary to produce one cubic meter of wood would not be very enlightening in terms of the associated environmental impacts. Additionally, the productivity differs between the land types. The yield of one hectare of cropland is generally higher than the yield of one hectare of grazing land (cf. Haberl et al. 2007).

$$\text{Ecological Footprint [gha]} = \frac{\text{apparent consumption [t]}}{\text{global yield [t/ha]}} \times \text{equivalence factor [gha/ha]}$$

Figure 2: Basic Relations between Apparent Consumption, Global Yield, and the Equivalence Factor in EF Calculation

Equivalence factors are an expression of the relationship between the global average productivity of each land type and the global average productivity of all land types. Cropland, for instance, has the equivalence factor 2.14 gha/cap (cf. Ewing et al. 2008), meaning that the global average productivity of cropland is 2.14 times as high as the global average productivity of all land types.

Weighting the ecological footprint with the help of equivalence factors means that the ecological footprint does not depict actual land use but that the area must be understood symbolically as the common unit of equivalents of biological productivity (van den Bergh/Verbruggen 1999a, Haberl et al. 2001; Erb 2004). A global hectare is thus a unit describing one hectare of fictional land with globally average productivity.

4. Overshooting biocapacity and the role of trade

It is in comparison with biocapacity that the ecological footprint unfolds its meaning. As mentioned before, the concept of carrying capacity strongly influenced the development of this indicator, suggesting that, just as an ecological system can only 'carry' a certain number of individuals of a species without being damaged permanently, there is only limited biocapacity available to meet human demands for bioproductive areas (Wackernagel/Rees 1996). If the ecological footprint lies above biocapacity, the difference between the two is called ecological deficit or overshoot (in the context of human societies' demand on ecosystems, this term was especially coined by Meadows et al. (1972) and Catton (1980)). The commonly suggested interpretation of overshoot is that the regenerative capacity of ecosystems is overused (Wackernagel et al. 2002) as is the case when more CO_2 is emitted than can be absorbed in the available carbon sinks. The consequence is the accumulation of CO_2 in the atmosphere. According to the Global Footprint Network, the global footprint was 18 billion gha in 2007, corresponding to approximately 2.7 gha/cap. In the same year, the globally available biocapacity was just 11.9 billion gha (or 1.8 gha/cap) (Ewing et al. 2010). The ecological footprint was thus more than 50% higher than the biocapacity. This is often interpreted as though the biosphere would require 1.5 years in order to compensate the annual draw on the regenerative capacities of its ecosystems due to human consumption or as though 1.5 'earths' were needed to meet our resource demand without permanently damaging the ecosystems' regenerative capacity.

Globally speaking, the occurrence of overshoot can be thought of as corresponding to interference with ecological regenerative capacity. On any level of scale below the global, however, overshoot can result from appropriation of geographically remote biocapacity via trade. If, however, the ecological footprint lies below biocapacity that alone is not an indication of there being no strain on the regenerative capacity of ecosystems (Wackernagel 1999b; Haberl et al. 2001). This may be due to the fact that the entire resource consumption is not included in the calculation of the ecological footprint and that, as an estimate of the human demand for resources, it is thus based on a conservative estimate.

Conceptually, the ecological footprint is based on various assumptions by which different forms of resource use exercised by human societies can be translated into a common unit, namely that of area demand and supply. The idea behind this type of aggregation is to reduce complexity in the depiction of society-environment interaction, thus facilitating communication about this subject matter. The broad popular response by which the ecological footprint was met during the last decade is a reflection of this strength of the ecological footprint as a tool of communication (cf. van den Bergh/Verbruggen 1999b).

Whether or not the so-called overshoot immediately implies a lack of sustainability is dependent on the level of scale at which the ecological footprint and the available biocapacity are being compared. At the global level, linking sustainability to an ecological footprint which does not exceed biocapacity seems most plausible. Here, the EF is an expression of the biophysical limits of the global system. That human activity is interfering with the regenerative capacity of ecosystems is hardly contested at this level of aggregation (Costanza 2000; Luck et al. 2001; Nijkamp et al. 2004). In using the ecological footprint to analyze trade relations and the concurring shifting of environmental burdens, the global level is not so much of interest as is that of individual states, regions or cities. But what does it really mean if overshoot occurs on any of these subglobal levels? How can we imagine one of the WWF's 'ecological debtor' or 'creditor' countries? "[H]ow dependent is our study population on resource imports from 'elsewhere' […]?" (Wackernagel/Rees 1996: 9).

For one thing, what is true for the country as a whole is not necessarily true for its parts. This divergence is illustrated by the case of New Zealand, which is one of the countries for which studies of the ecological footprint exist both on a national (Bicknell et al. 1998) and a subnational level (McDonald/Patterson 2004). In the year 1997/98, New Zealand's ecological footprint amounted to approximately 65% of its available biocapacity, on the national average. The urban areas of Auckland, Wellington, and Nelson, however, were all in overshoot. As is usually the case with cities, their ecological footprint was well above locally available biocapacity. At the same time – due to the relatively high population density – the per capita EF was well below the national average in all three regions (McDonald/Patterson 2004). In this case, the national average ecological footprint offers very limited possibilities for assessing the state of ecosystems within the country. A country might exhibit an ecological footprint which lies well below its biocapacity at the national level. This could, however, also result from some areas with strong overshoot being 'balanced' in the national average by other areas well within the bounds of their biocapacity (cf. Senbel et al. 2003; Fiala 2008). Locally, the ecological conditions might still be deteriorating, with all the (potential) consequences for the local population entailed.

Cities are prominent among those areas in ecological overshoot. This is an expression of their characteristic dependence on their *hinterland* (Folke et al. 1997; Luck et al. 2001). In their initial presentation of the ecological footprint, Wackernagel and Rees (1996) used the city as an illustration. The inhabitants of the urban space would not be able to survive if the city were placed under a glass cover, severing its ties to the rest of the world both in terms of inputs (water, air, resources) and the possibility of discarding unwanted outputs (emissions, waste). Life in such a city would probably be pleasant for a very limited amount of time and then quickly become impossible. But rather than pursuing the question of whether the self-sufficiency of a designated area would technically be possible, it seems important to examine whether or not this self-sufficiency would imply sustainability and should therefore be aspired to.

5. Tracing the footprint of trade

It is precisely this question of the role of self-sufficiency in the ecological footprint that brings us to the question of how trade can be assessed in this framework. It is an often-voiced critique of the ecological footprint that it has a negative bias against trade (e.g. van den Bergh/Verbruggen 1999b) and that if a state, a city or a region can only be sustainable if its ecological footprint lies within the bounds of its biocapacity, that would be tantamount to a plea for self-sufficiency in attaining sustainability (Ayres 2000). That the ecological footprint is calculated for apparent consumption means that a country's ecological footprint lies below its biocapacity if the balance of its domestic extraction and imports on the one hand and its exports on the other hand lies below its biocapacity. Self-sufficiency is not a prerequisite. On the global level, the ecological footprint clearly helps to illustrate that not all countries can simultaneously be net-importers of bioproductive area.

Trade in itself is not necessarily a problem in terms of sustainability. Theoretically, one densely populated country or (urbanized) region might exhibit an ecological footprint that lies above the local biocapacity but rely mainly on imports from a sparsely populated region consuming less than it has available within its borders (Rees 1992). Whether this is the case or not has to do not only with a country's population density but of course also with its geographical location and resource endowment leading to varying conditions of production from country to country (Nijkamp et al. 2004). The economical benefits to be gained were illustrated by David Ricardo with the concept of comparative advantage (Ricardo 1817) and are now part of the standard repertoire of neoclassical economics. Setting aside the fact that production in the present day economic system is not determined by a quest to reduce environmental impact, a form of ecologically sustainable trade (and the corresponding international division of labour) might be conceivable in which production of goods occurs wherever this is possible with the least possible damage to ecosystems (Costanza et al. 1995; van den Bergh/Verbruggen 1999a). This impact would become visible within the ecological footprint through increasing world yield leading to a reduction of the world average EF (cf. figure 2): If produced under ideal soil and climatic conditions, the yield for the respective product can be expected to rise, leading to a higher world average yield (Andersson/Lindroth 2001). In spite of much enthusiasm for the potential benefits to be gained from international trade for human well-being on the whole (e.g. Ayres 2000), the realisation of this potential is quite obviously not just around the corner in the currently given system of world trade which is neither ecologically sustainable nor socially just (Martinez-Alier 1987; Costanza 2000; Hornborg 2001; Hornborg et al. 2007). The ecological footprint of the economies of industrialised countries tends to feature 'a toe dug into Latin America and a heel ground into Asia', in metaphorical terms, which are doing anything but relieving the economic and social pressure in these regions.

What the ecological footprint can thus be used to illustrate is the dependency of a country or a region on the 'import of bioproductive area' rather than an *a priori* sustainability problem. Using the ecological footprint to analyse trade relations can point in the direction of where and to what extent the consumption within one country or region could potentially cause sustainability problems beyond its borders (cf. Erb 2002): Trade can lead to overusing biocapacity in the exporting countries. The ecological footprint further offers a tool for the illustration of how densely populated areas are dependent on importing contested resources and how consequentially the security of their supply is in no way guaranteed (Wackernagel/Rees 1996; Folke et al. 1997; Vuuren/Bouwman 2005).

International trade leads to environmental burdens and damages which frequently occur in other places than the corresponding consumption of goods and services. In order to be able not only to cite the structural and/or systemic evidence for this circumstance, it would be helpful to have an indicator with which to map the spatial disparities between final resource consumption and related environmental impacts. With an approach similar to the scheme of debtor and creditor countries proposed in the Living Planet Report, it is mainly conceptual work that has been done in terms of exploring the potential use of the ecological footprint in the analysis of trade relations (e.g. Andersson/Lindroth 2001; Wackernagel/Giljum 2001). By calculating the ecological footprint separately for domestic extraction, imports and exports, how much of a country's biocapacity is 'exported' can be assessed. Next to the distinction between ecological surplus and deficit, countries can be identified as net importers or exporters of EF (Andersson/Lindroth 2001). Due to the somewhat ambiguous depiction of sustainability in the ecological footprint framework, how straightforward the conclusion that Andersson and Lindroth suggest (ibid.: 116) as to whether the 'ecological capital' of countries is increasing or decreasing is contested.

While the ecological footprint is clearly a powerful tool in illustrating disparities in trade relations – the idea that a country takes up more 'space' through its physical trade balance than is available within its borders is quite an accessible one – much of the methodological work in finding approaches to analyse ecological burden-shifting through trade is moving in another direction. In order to be able not only to account for the direct material imports and exports, as the material flow accounting (MFA) framework currently makes it possible to do, but to further take into consideration the intermediate inputs that were required in the production of exported goods, it is necessary to open the black box of the economy with which MFA currently still operates. Next to LCA-based approaches for individual goods, the most common approach in economy-wide assessments has been the use of input-output data in order to trace the inputs into the production process (e.g. Hubacek/Giljum 2003).

6. Conclusion – are distribution conflicts leaving footprints?

Foreign trade leads to a draw on natural resources and an interference with the regenerative capacities of ecosystems that extends far beyond the borders of the importing country or region. It creates a rift between environmental impacts and the final consumption with which they are ultimately associated. At the same time, it is a stark illustration of the rift between the possibilities for political intervention, by national governments or international organizations, into economic decision-making and the dimensions of the environmental impacts that are associated with trade and the production of traded goods (cf. Fischer-Kowalski/Erb 2003).

Within the competition for ecological space which Wackernagel suggests can be illustrated with the help of the ecological footprint, the competition for bioproductive area figures prominently. Whether it is large-scale industrial agriculture or small-scale subsistence farming, human lives are dependent on the production and often also on the trade of biomass products. Issues pertaining to access to land are dominant in many environmental conflicts. Agricultural products have steadily become more important in terms of international trade: Between 1961 and 2007, the total volume of traded agricultural products increased by a factor of almost 6 from 178 million to over a billion tonnes per year (FAOSTAT 2010). In the EU27, for which physical trade data is available from Eurostat (2010), biomass made up 25% of all exports and 18% of all imports in 2007. At the same time, agricultural products play an important role in international stock markets with traded futures in various crops increasing steadily. Especially in terms of mapping ecologically unequal exchange, the EF is a rather intuitively accessible tool. The imagery of the area into which biomass flows, energy use, and land use-related activities are translated is quite powerful in making the claim on exporting countries visible. Using the available EF data, it would be possible to 'map the world' in terms of countries dependent on 'imported biocapacity' and to thus contribute to the analysis of power relations manifest in control over ecological resources in general and bioproductive land in particular.

Yet not all sustainability issues can be depicted using the ecological footprint. Along with what has already been discussed in this paper with regard to the ambiguity of the relationship between the ecological footprint and biocapacity, there are important forms of resource use and environmental burden that are simply not reflected in the ecological footprint. The EF is a snapshot of current resource use with an almost exclusive focus on biomass – it cannot take into account many forms of environmental pollution (McDonald/Patterson 2004), although some attempts have been made to calculate the area that would be needed for the absorption of pollutants (e.g. Folke et al. 1997on nitrogen and phosphate). The EF further cannot distinguish between more or less sustainable forms of land use. Often, intensification of agriculture will lead to a reduction of the ecological footprint because of the entailed increase in yields (van den Bergh/Verbruggen 1999a; Lewan/Simmons 2001). Due to the degradation of agricultural land that this form of production potentially causes and the effects on the regenerative capacities of ecosystems, larger ecological footprints could turn out to be more sustainable in the long run than smaller ones (Fiala 2008; Kitzes et al. 2009). This, however, lies beyond the field of vision in the EF snapshot; the eventual decrease in yield due to overuse of resources in agriculture cannot be depicted (cf. Vuuren/Bouwman 2005). The extraction and use of non-biomass resources is only marginally considered in the EF framework: The area occupied by e.g. mining sites for minerals is included as built-up land, the energy used in extraction and production processes is translated into carbon uptake land. And, just as is the case for fossil fuels, the limited availability and non-renewable character of minerals cannot be taken into account in the EF (Wackernagel/Rees 1996; Senbel et al. 2003).

Furthermore, while the ecological footprint and biocapacity may allow for conclusions about sustainability to be made at a global level (Ayres 2000), the threshold which would allow for a clear distinction between a sustainable and an unsustainable EF is lacking for sub-systems.

As strongly as the ecological footprint helps visualise potential environmental problems, it leaves the field of potential solutions hazy. Implications for political decision makers are not very straightforward (van den Bergh/Verbruggen 1999b). Alternatively, they turn out to be inapplicable in their generalisation. With a certain amount of exaggeration but nonetheless with some truth, it has been pointed out that the comparison between ecological footprint and biocapacity in principle only allows for one of three conclusions: If the ecological footprint lies below biocapacity, use more land. If there is overshoot, reduce consumption or population (Moffatt 2000; for an analysis of the correlation between ecological footprint and population see York et al. 2003).

On the one hand, the ecological footprint is continuously subject to methodological renovation and may eventually overcome some of the problems it currently faces. On the other hand, the need to better understand the shifting of environmental burdens through international trade is spurring the development of new tools to help us in quantifying these processes, such as the raw material equivalents (RME) of trade within the MFA framework (cf. Weinzettel/Kovanda 2009) and the exploration of embodied human appropriation of net primary production eHANPP (cf. Erb et al. 2009; Haberl et al. 2009). Notwithstanding, the ecological footprint has been essential in creating public awareness for the impossibility of unlimited growth in a physically limited world. It has helped to illustrate how high levels of consumption of natural resources within geographical regions and economic segments of society encroach upon the abilities of others to meet even their most basic resource needs.

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Abstracts

As a means by which uneven development is created and reproduced, international trade has received much attention. Foreign trade leads to a draw on natural resources and an interference with regenerative capacities of ecosystems that extend far beyond the borders of the importing country or region. Next to the structural and/or systemic evidence which can be cited, a method for the quantification of the redistribution of ecological burden which occurs through international trade is needed. The ecological footprint (EF) proposes to translate human societies' demand for natural resources into a bioproductive area requirement expressed in global hectares. The latter figure can be compared to the locally or globally available bioproductive area, in order to verify whether or not a given society is consuming natural resources within or beyond local or global limits. In communicating the draw of countries on biocapacity outside their borders through trade, ecological footprint analysis is a powerful tool. At the same time, it does not permit straightforward conclusions as to the sustainability of these trade relations. This paper outlines the ecological footprint methodology and, more specifically, examines how trade is accounted for in EF analysis in order to gauge the utility of the ecological footprint as a tool for quantifying ecological distribution conflicts.

In der Entwicklungstheorie ist der Rolle des internationalen Außenhandels (insbesondere im Zusammenhang mit ungleicher Entwicklung) bereits viel Aufmerksamkeit geschenkt worden. Mit diesen Außenhandelsflüssen gehen Beanspruchungen natürlicher Ressourcen und Eingriffe in die Regenerationsfähigkeit von Ökosystemen einher, die weit über die Grenzen des importierenden Landes hinausreichen – dafür liegen strukturelle bzw. systemische Belege vor. Doch wird darüber hinaus eine Methode zur Quantifizierung der Umverteilung von Umweltbelastungen durch internationalen Handel benötigt. Der ökologische Fußabdruck übersetzt die gesellschaftliche Nachfrage nach natürlichen Ressourcen in eine (hypothetisch) damit einhergehende Nachfrage nach bioproduktiver Fläche, die in der Einheit des „globalen Hektars" bemessen wird. Aus dem Vergleich des ökologischen Fußabdrucks mit der vorhandenen bioproduktiven Fläche soll ersichtlich werden, ob der Ressourcenkonsum einer Gesellschaft gege-

bene ökologische Grenzen überschreitet oder nicht. Unter anderem weil er die Auslagerung von Umweltauswirkungen durch internationalen Handel bildhaft veranschaulicht, ist der ökologische Fußabdruck als Kommunikationsmittel ein wirkungsvolles Instrument. Jedoch erlaubt er keine direkten Rückschlüsse auf die Nachhaltigkeit der jeweiligen Handelsbeziehungen. Im vorliegenden Artikel wird die Methode des ökologischen Fußabdrucks umrissen, das spezielle Augenmerk liegt hier darauf, wie der Außenhandel darin wiedergegeben wird, um die Nützlichkeit dieses Ansatzes in der Quantifizierung von ökologischen Verteilungskonflikten zu bewerten.

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Farmer Participatory Research: An Approach to Fostering Community-led Innovation in Smallholder Agriculture

1. Introduction

In this article we suggest farmer participatory research as an approach to community-led innovation aimed at finding solutions to agronomic challenges in smallholder agriculture. We do this in recognition of the overriding theme of this special issue, i.e. uneven development across spatial and temporal scales. We acknowledge the wide range of applications of the term 'uneven development', as well as its political history. In our interpretation, uneven development describes economic disparities between continents, countries or societies. Applied to the smallholder agriculture of sub-Saharan Africa, 'uneven development' typically addresses global trade or international political economy concerns as well as unequal access to information, natural resources, financial services or social networks with political weight. Our contribution to this special issue draws attention to the agronomic challenges that smallholder farmers face in their daily struggle for more sustainable and secure livelihoods. These challenges are reflected in soil quality decline, increasingly variable weather conditions, pest and disease incidents, and, as a consequence of all these, increased crop production risks. An article about 'agronomic challenges' and smallholder response strategies is not trivial, exotic or outside the scope of this issue. Rather, such approaches offer relevant insights into local-level sustainability arising in large part due to the deficiencies in world political and economic structure. Undoubtedly, the problem of uneven development needs to be addressed at all scales. In this contribution, we offer one approach that can be taken at the local level, namely community-led innovation in smallholder agriculture to enhance the sustainability and well-being of local socio-ecological systems.

Finding solutions to agronomic challenges is important, because smallholder agriculture is confronted with a range of ecological obstacles that put food production at risk. This is of particular relevance in sub-Saharan Africa (Resnick 2004; Asenso-Okyere/Davis 2009). Although some progress has been made, it is still the region with the highest share of people living in poverty and food insecurity. Despite rapidly expanding urban and peri-urban areas, the majority of people living in poverty are rural and depend on agriculture (Ambrosini 2002; Waithaka et al. 2006). For that group, agriculture is a major livelihood strategy, yet one confronted with uncertainties and stress. At regional level, food crop productivity has more or less stagnated over the last 40 years. While crop productivity is not the only agricultural performance indicator, it matters to farmers whose lives depend on farming (Lobell et al. 2009). Beside food production, agriculture has essential social, cultural and environmental functions. Considering the paramount role of multi-functional agriculture for sustainable livelihoods, the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD 2009) calls on governments to make radical changes in the way farming is supported.

The conventional development discourse emphasises science as the main source of innovation. While science is undoubtedly an important driver for innovation and change, agricultural research products often do not pass the stage of being good but isolated ideas. Following Schumpeter such ideas are, in the best case, nothing more than inventions. Such inventions remain irrelevant to farmers, if, as Assefa et al. (2006) suggest, they are not transformed into innovations by entering into the complex relations and interactions of people and institutions in wider socio-economic, cultural and political contexts. What many of these inventions have in common is the limited scale employed by the farmers that apply them. At the latest since Robert Chambers' plea for 'Farmers first' (Chambers 1989), smallholder agriculture is recognised as a complex, diverse and risk-prone undertaking. Supposedly benign technologies and agronomic practices generated by research do not always match with the needs and priorities of smallholder realities in sub-Sahara Africa. Moreover, it is now widely recognised that farmers themselves are important sources of new ideas. Farmer participatory research, as presented in this article, fosters community-led innovation and puts farmer research committees into the driving seat of technology development.

We wrote this article from an applied development research perspective. Applied development research is driven by practical development issues, such as degrading natural resources, declining access to land and water, or opportunities to tap local and international niche markets. Applied development research is empirical, draws on middle range theories and envisions the practical application of research insights. It is not a discipline per se, but describes a field of operations that draws on theoretical and methodological insights from natural, technical and social sciences. In our work, attempts to address uneven development, being the main theme of this article, begin with a simple question: how can farmers, within the given opportunities and constraints of the world-system, further develop multi-functional agriculture that contributes to household food security and sustainable livelihoods, while safeguarding ecosystem quality and contributing to societal well-being? Answers to this question shall help farmers and their representatives to identify more secure livelihood opportunities that otherwise remain neglected.

In the proceeding section we review some of the main arguments as to why technology transfer has so rarely been effective in sub-Sahara Africa. The subsequent section embeds farmer participatory research in the broader innovation systems debate. Based on this, we show how farmer participatory research works in practice. This article concludes with remarks about the value of applied development research for fostering innovation in smallholder agriculture in sub-Saharan Africa.

2. Why technology transfer failed

The transfer of technology model is a linear research and technology application process. It embodies a particular way of thinking about the role of science and its relationship with other sources of knowledge. In agriculture, this has been widely manifested in the idea of extension officers as specialized intermediary agents to transfer on-station research findings into farmer fields (Kerkhoff/Lebel 2006). Farmers are seen as either 'adopters' or 'rejectors' of technologies, but not as a source of technical knowledge, technologies and practices. As Kerkhoff and Lebel (2006) note, the traditional transfer of technology model assumes an objective truth that the scientists pass on to the farmers via extension officers, and farmers are assumed to make decisions independently on a technical basis (figure 1).

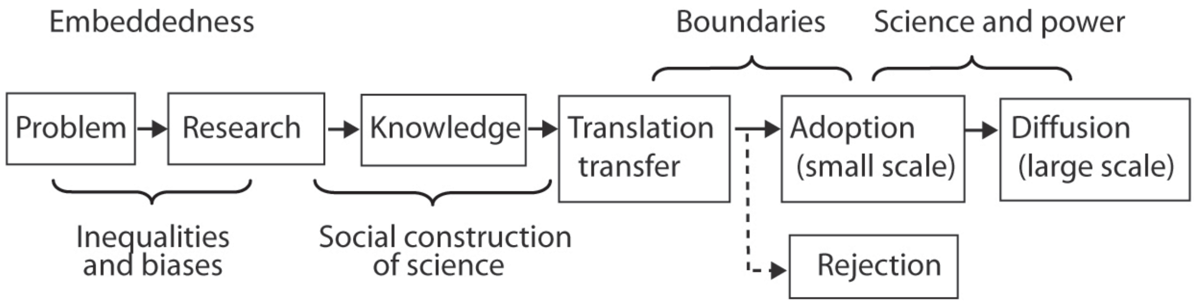

Figure 1: Critiques of the transfer and translate model
Source: adaption from Kerkhoff/Lebel (2006: 458)

Following attempts to introduce Green Revolution agriculture in sub-Saharan Africa from the 1960s onwards, transfer of technology thinking has dominated agricultural development (Critchley 2000). The basic assumption has been that technology packages of improved seeds, mineral fertilisers and synthetic pesticides handed over to farmers would increase agricultural productivity as rapidly as had been the case in south Asia. Agricultural technologies developed on research stations and further tested in researcher-managed on-farm demonstrations performed well, but were rarely replicated on farmer fields. It is now well documented that, in most parts of sub-Saharan Africa, the Green Revolution has failed (Kijima et al. 2011; Omanya et al. 2007).

But not only the type of agricultural technology is to be blamed, but also the way agricultural technologies have been developed and disseminated among farmers. Since the early 1960s, the 'diffusion of innovation' model was widely applied to frame and to plan for technology transfer from research stations via extension service providers to farmers (Rogers 2003). The model emphasises those social networks through which agricultural technologies spread over time. The mainstream 'diffusion of innovation' thinking perceives technology dissemination as a stepwise process, whereby new ideas, technologies and practices are adopted by different categories of people at different times. Rogers suggest that people should be classified into different adoption categories, rangeing from early to later to late majority and laggards (Rogers 2003; Rogers/Kincaid 1981).

For several decades, the extension service providers were blamed for the lack of adoption of agricultural technologies by farmers. But extension services also face several challenges, which include chronic under-funding since the 1980s, poor capacity to cater to diverse farming and livelihood strategies and to enable countervailing powers of smallholders to tackle unfair competition on world markets (Feder et al. 1999; Sharma 2002; Sulaiman/Hall 2002). What followed were poor records of extension services, in particular the World Bank-funded Training and Visit schemes. Technology package transfer from national research stations to farmers often failed because extension services could not respond to the many changes within the socio-economic, political and ecological environments within which it exists (Pretty 1995; Wallace 1997).

With time, criticism of the 'diffusion of innovation' model for neglecting the complexity of smallholder agriculture as well as the risk-prone context in which farmers operate grew. For example, the 'diffusion of innovation' model presents a rather one-way communication path, whereby researchers are the sources of agricultural information and technologies, technology dissemination was the responsibility of extension service providers, and the adoption of extended technologies is done by farmers. In reality, extension services providers and farmers themselves are co-developers of technologies (Probst et al. 2003; Wettasinha et al. 2008). Secondly, 'diffusion of innovation' thinking suggests that farmers decide between the adoption or the rejection of a technology or practice. While this is true for a certain set of technologies (e.g. new crop varieties), farmers rarely adopt the technology package as a whole. In reality, farmers carefully select technology components, sometimes farmers sequence the implementation of technologies (Leeuwis/Van den Ban 2004). Third, the 'diffusion of innovation' model was to a large extent developed under North American conditions, spearheaded by Land grant universities. Towards the end of the past century, partly influenced by several European donor agencies, the chapter of classical technology transfer thinking as briefly outlined in this section came to a close. This does not mean that transfer of technology is not practiced but only that it gradually disappeared from the official development agenda.

3. Innovation thinking in agriculture

Over a period of two decades, innovation concepts entered the agricultural research discourse. Yet these concepts refer to something intrinsically human. Innovation is, as Fagenberg et al. (2005) put it, ultimately linked to the human desire to think about new and better things and to try them out in practice. Innovation can be ecological, technical, economic, social or organizational. "Innovation is: production or adoption, assimilation, and exploitation of a value-added novelty in economic and social spheres; renewal and enlargement of products, services, and markets; development of new methods of production; and establishment of new management systems. It is both a process and an outcome" (Crossan/Apaydin 2010: 1155). Innovation also communicates 'change' and 'transition'. For example, Sulaiman et al. (2006) or Hall et al. (2010: 14) understand innovations as "changes that takes place in societies, when knowledge, technology and information is made available and is put into socially and economically productive use."

Innovation is also a process of technological and institutional change at farm (and higher) levels that impact on productivity, income or sustainability (Röling 2009b). Leeuwis and Van den Ban (2004: 61) defined innovation as "a new pattern of coordination between people, technical devices and natural phenomena". This definition is rendered exhaustive by incorporating whole elements and components that innovation encompasses in actual practice. They consider innovation in a wide and to some extent co-evolutionary sense. According to them, changes 'never come alone', and often include technical, social and organizational elements. Or as Hellström (2007: 148) puts it: "eco-innovation must, in order to succeed, also build on relevant social structures and in some cases the innovation should also be able to influence these structures."

At a higher level, innovation takes place within a particular innovation system. An innovation system incorporates all actors that are needed to solve a particular problem. Innovation systems do not exist independently of a problem, but rather it is the problem that defines system boundaries. Because innovation systems are defined for a particular purpose, system boundaries may shift or the system as a whole may dissolve with time. In agriculture, innovation systems are frequently organised around production or market problems at national and local level (see innovation platforms of FARA; www.fara-africa.org). They ensure information flow in general or directed for a specific purpose (Metcalfe/Ramlogan 2005).

Innovation systems in turn are components of the larger innovation context, something labelled 'innovation ecology'. Innovation ecology is, as Metcalfe and Ramlogan (2005) point out, 'no system of itself until subsets of the actors are connected with the intention of promoting innovation'. Wulf (2007) defines innovation ecology as 'the environment comprising interconnected institutions, laws, and policies that create an innovation infrastructure that includes education, research, tax policy, and protection of intellectual capital'. Ecology as a metaphor helps to compare innovation dynamics to ecosystems. Each component of a given innovation ecology has a function and the ecology as a whole must be adaptable to environmental changes.

Several factors influence the innovation ecology of a given region or territory in which people are engaged in agriculture. These factors may include agricultural support services and micro-finance institutions, the nature of governmental policies, the availability of financial services or the operational of agricultural advisory programmes. The nature of the innovation ecology certainly influences the type of innovation that innovation systems can bring forth.

Interactions within innovation systems are typically non-linear with a range of decentralised decisions taken. All living organism, human and social systems are complex dynamical systems. All such systems have similar generic properties, including communication, iteration, cooperation, conflict generation or resolution, and organisation. In that sense, innovation is the emerging property of a 'soft system': new products, technologies or practices are no longer the result of a linear chain of events, but they emerge from the interaction among system actors. It considers innovation as the emerging property of social interaction and their interactions with the environment.

Boundaries of innovation systems cannot be determined objectively, but they are socially constructed. This implies that the definition of system boundaries created by researchers is likely to differ from those of extension service providers and from those of farmers. Everything that lies outside the system boundaries belongs to the system context, which is outside the sphere of influence from the perspective of the viewer or actor. In other words, technologies developed at the research station are – from a farmer's point of view – developed beyond their innovation system boundaries. If this is true, then the same applies to researchers, i.e. technologies developed by farmers are – from a researchers' point of view – developed beyond their innovation system boundaries.

With the help of organising forces, complex dynamical systems aim for the maintenance of their internal structure. The structure of a given system communicates with its environment and receives 'inputs' (e.g. in the form of external irritation), but in most cases they are not considered relevant. Externally developed solutions are beyond people's system boundaries. From a systems theoretical perspective, the imposition of behaviour onto smallholder agriculture is bound to fail and at best will result in compliance for material incentive. Supporting farmers to strengthen agriculture, notably to increase ecological sustainability, cannot be achieved through instructive interaction and expert advice. It is assumed that most of the solutions that farmers are able to implement in response to agricultural challenges lie within farmers' system boundaries. This also changes the innovation ecology, hence the conditions under which change and transformation takes place.

The term 'attractor' is a useful metaphor to describe what happens when a system resists outside intervention. Attractors can be seen as "a state or a reliable pattern of changes (e.g. periodic oscillations toward which a dynamical system evolves over time and to which the system returns after it has changed" (Coleman et al. 2007: 5). An attractor is an 'attractive patterns of human behaviour', an organised dynamic structure. These have two characteristics: an organised dynamic structure and resistance to disturbance. Following outside irritation, the attractor guides the system back to a new attractor.

4. Farmer participatory research in practice

In this section we turn to Hoima district, mid-western Uganda, where we observed farmer participatory research in practice. Hoima, which borders Lake Albert to the west, covers an area of 5,775 square kilometres and has a population of 341,700 people (Buyinza et al. 2008). The average annual rainfall is around 1,435 mm, with two peaks in April and October/November. The annual average temperature is 22.6°C (Uganda Department of Meteorology 2007 cited in Fötsch 2008). Small variations in temperature and humidity characterise Hoima's climate (Buyinza et al. 2008). The vegetation within the district is predominantly savannah grasslands ranging from medium altitude moist forests through forest/savannah mosaic and swamp to post cultivation communities (Oluka-Akileng et al. 2000 cited in Buyinza et al. 2008). Soils are mainly yellowish-red clay loams on sedimentary beds (Siriri/Bekunda 2001 cited in Buyinza et al. 2008). 95% of Hoima's inhabitants are involved in farming activities (Fötsch 2008) and the rain-fed and manually cultivated agricultural production mainly comprises of food crops as maize, cassava, millet, beans and sweet potatoes as well as cash crops such as tobacco, cotton, sugarcane (Buyinza et al. 2008; Fötsch 2008).

Hoima is served by the National Agricultural Research Organisation (NARO) Zonal Agricultural Research and Development Institute, which is specialised on seed multiplication, notably cassava mosaic virus-free planting material. Access to agricultural information and technologies was sporadic, extension on sustainable crop production offered by several national and international Non-Governmental Organisations (NGOs). Overall, the level of knowledge about effective sustainable agricultural practices is low. Soil fertility decline has been a concern of both farmers and external service providers. This concern increased in the wake of the privatisation of public extension services and a shift in focus to agricultural commercialisation. Despite access to information about sustainable agricultural practices being low, farmers had comprehensive knowledge about soil types and qualities. Names and descriptions for different soils and experiences with managing the more difficult soil types in the dryer parts of the region or on slopes helped them to take crop management decisions. Such local knowledge pools served as entry points for farmer participatory research.

In 2004, as part of a larger research project, one NGO and an international agricultural research centre together with two farmer groups and the Zonal Agricultural Research and Development Institute joined forces and engaged in a three-year experimentation in a quest to strengthen sustainable agricultural practices. Respective activities were embedded in the 'Enabling Rural Innovation' framework, aimed at developing profitable agro-enterprises while safeguarding natural resources (for details, see Kaaria et al. 2008). The implementation of the ERI process was mentored by the NGO, soil scientists, agronomists, resource economists and social scientists hosted by the international agricultural research centre were responsible for accompanying scientific research. As far as possible, the research team integrated insights and observations within their contribution to build theories around field level action.

Each of the farmer groups nominated a research committee, which was offered farmer participatory research training by members of the NGO and research team. These trainings started off with visits to the National Agricultural Research Organisation (NARO) Zonal Agricultural Research and Development Institute, which exposed farmers to agronomic experiments. In addition to such exposure visits, farmers received training in research priority setting (e.g. the formulation of research questions for improving productivity and soil fertility management), experimental designs and the monitoring and evaluation of agronomic experiments. An agronomic evaluation matrix identified constraints in production, and identified opportunities for increasing the productivity and competitiveness of both food and cash crops.

Following the trainings, farmers took responsibility for setting out their own experiments. Land allocation, planning and implementation of the trials, and evaluation were entirely community-led. Research questions arose in connection with new food and cash crops farmers opted to experiment with. Decisions regarding the prioritisation of food and cash crops were informed by both household and market demand. Over the three years, farmers conducted organic soil fertility management trials (to test management options suited to different soil and landscape conditions) and variety trials (testing selected food and cash crops). Farmers experimented with a wide range of food and cash crops, including ginger, garlic and onions as well as cassava mosaic virus-free cassava varieties. The experiments helped them to test crop varieties under specific sustainable agriculture practices, which included mulching, composting and the use of animal manure as organic fertilisers. Trials were also conducted to strengthen nutrient cycling and soil organic matter replenishment. All experiments were conducted on community learning plots, in most cases managed by the entire community.

Evidence from the research project in Hoima suggests that farmer participatory research is an effective approach for enhancing farmers' capacities to sustainably manage their agro-ecosystems. One farmer describes the benefits that arose from training in farmer participatory research as follows: "The things we started doing came through trainings especially on soil conservation because like us we have little soil, and so you find that you protect your soil from erosion, mulch to ensure water conservation, do not do burning, also advise your neighbours not to mismanage soil etc. and also plant trees so that you ensure nature protection. Those are some of the benefits. We also have some things we have sold together like soya bean which we collect as a group, and the buyer comes to buy from the group and you find that we get money as a group and people start even to admire you" (Individual interview I16 with Kugonza group[1]). This statement indicates that farmer participatory research does more than bring about ecologically relevant outcomes at farm level. Benefits from enhanced agro-ecosystem management are further translated into increased market penetration at group level. Altogether, this results in high recognition within their social environment which in turn feeds back into increased self-confidence for continued experimentation. Another study conducted in the same area confirms that experimentation has a positive effect on farmers' self confidence, which is further expressed in a high willingness among farmers to share their knowledge and skills on on-farm experimentation and act as multipliers through training fellow farmers (Prehsler 2010).

The ability of farmers to plan, implement and evaluate on-farm experiments are an indication of a new attractor. Farmers' experimental knowledge supports farmer-driven inventions and develops farming systems and procedures, identifies new approaches and appropriate technologies (Röling 2009a). The delivery of external, usually science-based, inventions is not comparable to the adoption of a farmer-developed add-on innovation. The latter is a dynamic, human pattern-disrupting yet short-term achievement, while the former is a complex learning process similar to obtaining a degree (Röling/Jiggins 1998).

Example

Pretty et al. (2006) report on a study of 286 interventions in 57 developing countries across the world where the impacts of various sustainability-enhancing agricultural practices were assessed: integrated pest and nutrient management, use of conservation tillage, aquaculture, water harvesting, agroforestry and integration of livestock in farming systems. In the 12.6 million farms that were studied, a net increase in crop productivity by 79% was observed along with an improvement in critical environmental services. Those projects dealing with adequate use of pesticides reported a 71% decline in their use, while increasing yields by 42%. The overall water-use efficiency increased considerably by enhancing soil fertility and reducing evaporation, using low-tillage techniques, improved varieties and inducing microclimatic changes to reduce crop water requirements. Annual gains of 0.35 t C per hectare in carbon sequestration potential offered new opportunities for households to generate income from carbon trading schemes. Within a period of four years, there was a dramatic increase in the number of farms (56%) and area (45%) that adopted sustainable technologies and methods, with poor households benefiting substantially.

With time, on-farm experiments gained momentum and translated into common day-to-day farming practice, being well-integrated into farmers' knowledge system. They helped farmers to develop an experimental culture towards more adaptive agro-ecosystem management. At the same time, dependencies on external service providers were reduced. Information about the ongoing community-led experiments spread to other communities, which resulted in spontaneous farmer-to-farmer exchange visits. On-farm experiments are not new, yet handing over responsibilities for planning, managing and analysing them from researchers to farmers is rarely practiced. The existence of such farmer-led experiments therefore resulted in various official visits by sub-county and district officials.

Anecdotal evidence also suggests that farmer participatory research activities changed the perceptions of actors outside the immediate framework. For example, the privatised extension service at local government level now considers farmer participatory research as an important method of improving technology co-development as well as transfer. At the same time, changes within the innovation system became significant barriers to the further scaling out of farmer participatory research processes (scaling out research findings or technologies was anyway not intended). Due to limited funds, the public agricultural research stations left the project team. Also the intervention as such had limited outreach to other farmers. The assumption that farmer participatory research would spread across communities could not be verified.

This is not surprising, because the spill-over effects of training programmes at community level may be greater for agricultural technologies that have short-term benefits, and which require some degree of coordination to be most effective. Direct involvement of households in programs and organizations that promote such technologies may be necessary to ensure technology diffusion throughout communities (Jagger/Pender 2003). A review by Shiferaw et al. (2007) highlights that an excellent option to ensure adoption and adaptation of innovations is to develop them iteratively, in collaboration with the farmer groups.

5. Conclusion

Sustainable agriculture requires flexible, self-organised responses by farmers to natural resource-related challenges. Research and extension methodologies to support sustainable agricultural development should therefore aim to enhance farmer capacities favourable to sustainable agriculture, rather than to achieve the adoption of standardized technologies. These capacities include sound ecological knowledge, observational, analytical and experimental skills, and an inclination towards collectively allowing farmers to make better, informed decisions for location-specific agro-ecosystem management (Van de Fliert 2003, 2006).

Irritation through challenging the attractor, as carried out through farmer participatory research, is one of the few non-instructive support measures with chances to enhance learning, invention and innovation. Support measures ensure a widening of famers' perspectives, i.e. an increase in options and opportunities. This draws on various sources of information and is a process of opportunity identification by farmers themselves. In the course of time, performance of interventions in the field of agricultural research, water management, natural resource management and integrated rural development depend on a mutual consent with local priorities and trends (Zoomers 2006).

Multifaceted explanations of poverty and uneven development in agriculture, more so now than in the past, heighten confusions and tensions and mask an adequate understanding of the process of putting 'development' into practice. Farmer participatory research does not address structural deficiencies within the world economic and political system. However, farmer participatory research does make use of the room for manoeuvre that farmers have towards more sustainable agriculture. Applied developed research helps to identify that room for manoeuvre and to support farmers in broadening opportunities. An innovation systems perspective helps provide understanding of how this can be used to develop new local action and to translate it into comprehensive spatial and temporal innovations.

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Abstracts

Innovation is ultimately linked to the human desire to think about new and better things and to try them out in practice. In this article, we suggest farmer participatory research as an approach to foster community-

led innovation in smallholder agriculture in western Uganda. Farmer participatory research is a process of designing and implementing on-farm trials to test and further improve agricultural technologies and agronomic practices. For smallholder farmers who lack access to formal agricultural research and support services, farmer participatory research supports community-led innovation aimed at improving ecological sustainability agriculture.

Innovation ist mit dem menschlichen Wunsch verbunden, über neue und bessere Dinge nachzudenken und diese in der Praxis auszuprobieren. In diesem Artikel schlagen wir „partizipative bäuerliche Forschung" *(farmer participatory research)* als einen Ansatz zur Förderung gemeinschaftlich entwickelter Innovation in der kleinbäuerlichen Landwirtschaft Westugandas vor. Partizipative Forschung von BäuerInnen ist ein Prozess, in dem Experimente direkt in den Landwirtschaftsbetrieben entworfen und implementiert werden, mit dem Ziel, landwirtschaftliche Technologien und agronomische Verfahren zu testen und zu verbessern. Für KleinbäuerInnen, die keinen Zugang zu institutionalisierter landwirtschaftlicher Forschung und den damit verbundene Dienstleistungen haben, fördert partizipative Forschung gemeinschaftliche entwickelte Innovationen, die darauf ausgerichtet sind, die ökologische Nachhaltigkeit von Landwirtschaft zu verbessern.

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Karin Fischer, Christian Reiner, Cornelia Staritz (Hg., 2010): Globale Güterketten: Weltweit Arbeitsteilung und ungleiche Entwicklung. *Wien: Promedia (= Historische Sozialkunde/IE, Bd. 29), 260 Seiten, 24,90 Euro*

Die seit den 1990er Jahren vielerorts proklamierte „Globalisierung" wurde oft anhand ökonomischer Umstrukturierungen diagnostiziert. Festgemacht an Indikatoren wie der Zunahme internationaler Handelsströme oder dem Anteil transnationaler Konzerne am Welthandel, blieben Veränderungen der Produktionsabläufe auf Unternehmensebene oft unterbelichtet. Das *outsourcing* von Produktion ging nämlich vielerorts mit ihrer Ausgliederung aus dem Kerngeschäft international agierender Konzerne einher, sie wurde stattdessen von Zulieferbetrieben in der globalen Peripherie übernommen. Die Rede von *manufacturing without factories* begleitet Sportartikelhersteller ebenso wie Elektronikkonzerne.

Bearbeitet wurde dieses Themengebiet im Rahmen der Debatten um globale Güterketten, Wertschöpfungsketten oder auch globale Produktionsnetzwerke. Der vorliegende Sammelband, herausgegeben von Karin Fischer, Christian Reiner und Cornelia Staritz, greift diese Ansätze auf und widmet sich der Thematik aus entwicklungspolitischer Perspektive. Besonderes Augenmerk gilt dabei internationalen Machtverhältnissen und der „Frage, wer die Profiteure sind und wie sich global gestreute Produktion auf die Entwicklungschancen der beteiligten AkteurInnen in armen Ländern oder Regionen auswirkt" (S. 12). Untersucht wird etwa, welche „AkteurInnen in armen Ländern […] durch den Zugang zu kaufkraftstarken Märkten und zu Technologieführern wertvolles Wissen zur Aufwertung eigener Unternehmensaktivitäten erlangen" können, ob sie „lediglich als untergeordnete, abhängige Grenzproduzenten in Produktionsnetzwerke integriert" werden und wie sich „Löhne und Arbeitsbedingungen für die ArbeiterInnen durch die Einbindung in globale Güterketten" verändern (S. 11).

Dieser Akzent hebt sich vom Mainstream der Debatte um globale Wertschöpfungsketten kritisch ab, die sich oftmals bloß individuellen Potenzialen des industriellen *upgrading* in der globalen Peripherie annimmt. Fallstudien werden dann als Belege bemüht, um die Chancen der weltwirtschaftlichen Umstrukturierungen hervorzuheben. Diese etwas verkürzte Betrachtungsweise wird im vorliegenden Sammelband durch einen breiten Blick auf unterschiedliche Debatten vermieden. Neben den dominanten Ansätzen zu *Global Commodity Chains* bzw. *Global Value Chains* (Gary Gereffi) werden einerseits neuere Zugänge zu *Global Production Networks* (Jeffrey Henderson) sowie andererseits traditionellere Auseinandersetzungen der Weltsystemtheorie zu Güterketten (Immanuel Wallerstein) rezipiert. Eine breite konzeptionelle Einführung durch die HerausgeberInnen wird durch eine der zentralen Proponentinnen in der Debatte, Jennifer Bair, ergänzt, die aktuellere Ansätze kritisch reflektiert und auf weltsystemtheoretische Interventionen verweist. Darauf folgen elf empirische Untersuchungen, die sich auf unterschiedlichen methodischen Grundlagen mit den Entwicklungen in einzelnen Sektoren auseinandersetzen. Besonderes Augenmerk gilt dabei den sozialen Auswirkungen, Entwicklungspotenzialen und Arbeitsbeziehungen sowie den globalen Rahmenbedingungen der beschriebenen Prozesse.

Gerade die Integration der weltsystemtheoretischen Zugänge öffnet das Feld für eine historisch fundierte kritische Betrachtung der Prozesse auf Unternehmensebene. Das wird sowohl konzeptionell – in Jennifer Bairs Beitrag – als auch empirisch – in Andrea Komlosys historischer Analyse der globalen Güterketten des Welthandels – berücksichtigt. Andere Fallstudien erfassen rezentere Entwicklungen, wobei sie auf eine große Bandbreite von Fällen Bezug nehmen: Von der Lachsindustrie (Karin Fischer) über Kakaoproduktion (Niels Fold), Fair Trade in der Zimtherstellung (Christiane Stephan, Andreas Stamm), Sportartikelproduktion (Wolfram Manzenreiter), Elektronik- (Leonhard Plank, Cornelia Staritz), Automobil- (Lukas Lengauer, Florian Wukovitsch) und Pharmaindustrie (Zeller) bis hin zur Macht globaler Supermarktketten (Elisabeth Aufhauser, Christian Reiner) wird ein breiter empirischer Bogen gespannt. Die spezifische Bearbeitung der Frage der Veränderung der Qualität der Arbeit an den oberen und unteren Enden von Wertschöpfungsketten (Jörg Flecker) sowie der internationalen Regulierung von Unternehmen (Bernhard Ungericht) runden das Bild ab.

Der Sammelband „Globale Güterketten" führt eine zentrale internationale entwicklungspolitische Debatte in den deutschsprachigen Raum ein. Besonders positiv beeindrucken die Mischung aus konzeptionellen und theoretischen Überlegungen mit empirischen Fallstudien in verständlicher Sprache sowie die kritische Perspektive auf ökonomische Umstrukturierungen auf Ebene der Unternehmensorganisation. Die jüngere Geschichte der Rezeption der Güterkettenansätze seitens internationaler Organisationen sowie daraus abgeleitete entwicklungspolitische Leitlinien werden hingegen leider nicht explizit berücksichtigt. Für Interessierte an aktuellen entwicklungspolitischen Diskussionen sowie an mikro-ökonomischen Prozessen der Globalisierung ist das Buch aber dennoch besonders empfehlenswert.

Bernhard Leubolt

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