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

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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).

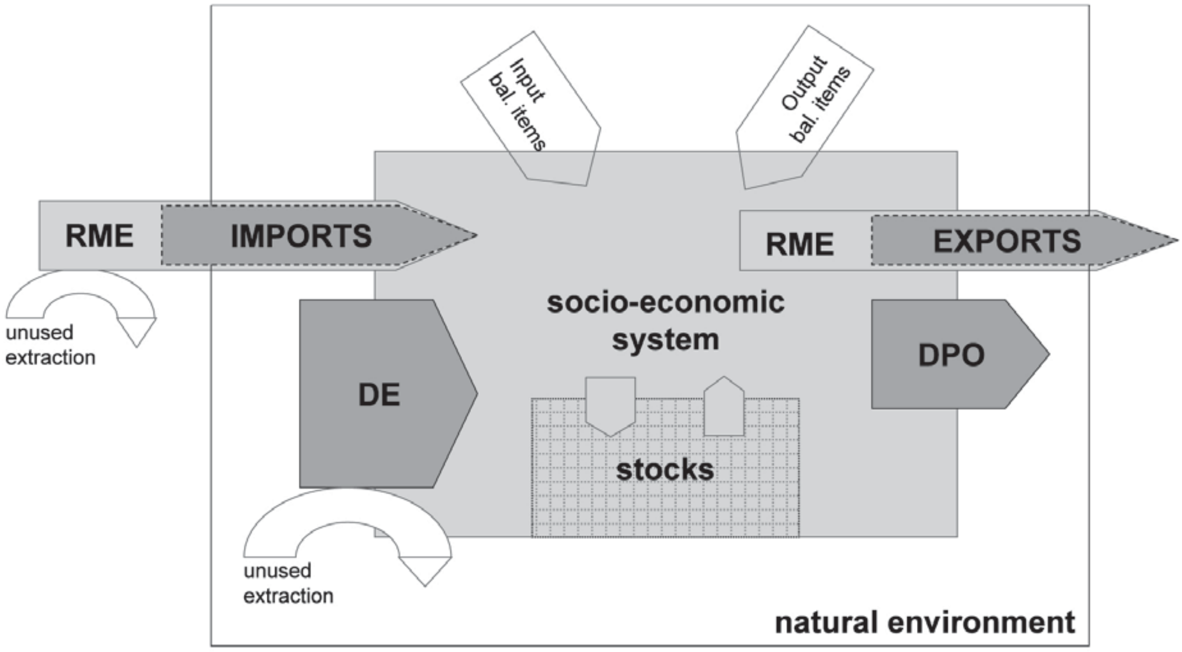


Figure 1: Schematic representation of economy-wide MFA
Source: Eurostat 2009, modified

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 bookkeeping 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.

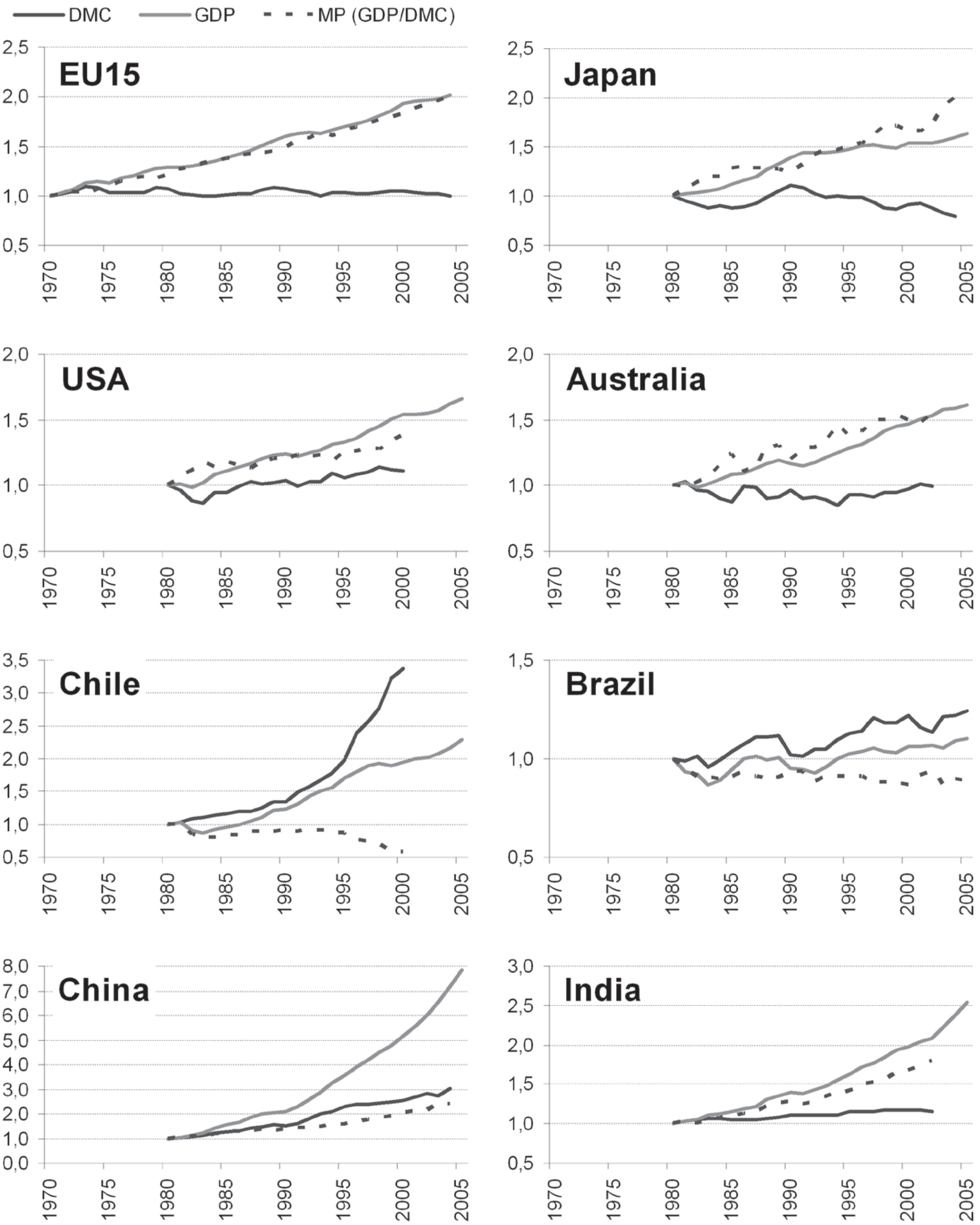
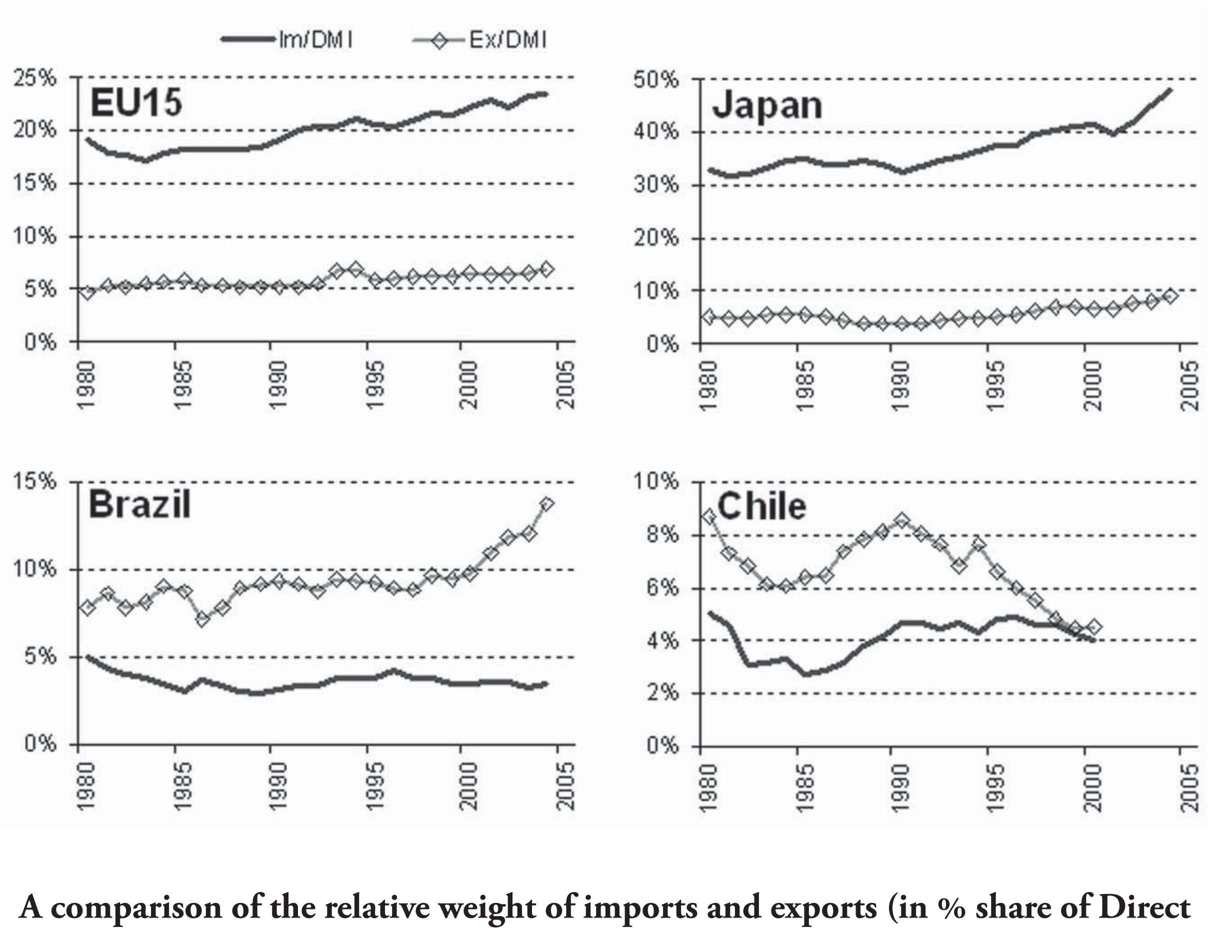


Figure 2: patterns of delinking: trends of material use (DMC), economic growth (GDP) and material productivity (MP) during the years 1970/80 to 2000/05

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.

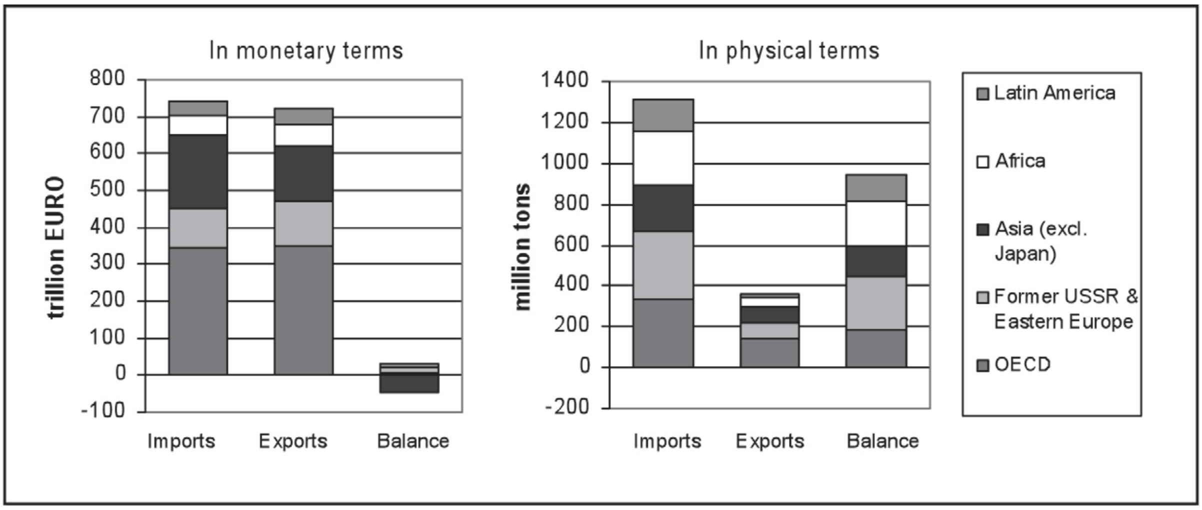


Figure 4: Monetary versus physical trade balance of EU-15, 1999
Source: Giljum/Hubacek 2001

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.

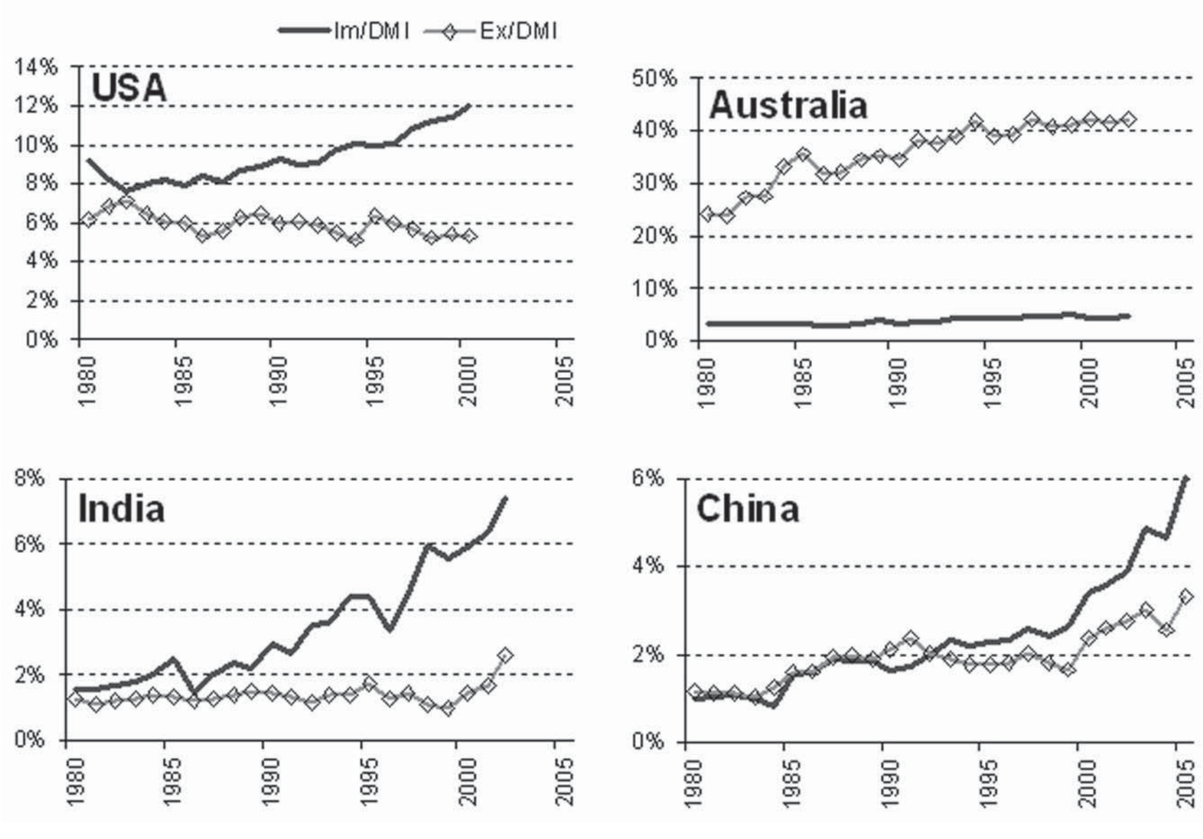


Figure 5: A comparison of the relative weight of imports and exports (in % share of Direct Material Input, DMI)

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'.

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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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