Fair Enough?

Ecologically Unequal Exchange, International Trade, and Environmental Justice

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Martin Oulu

LUND
UNIVERSITY

DOCTORAL DISSERTATION
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Fair Enough? Ecologically Unequal Exchange, International Trade, and Environmnetal Justice

Abstract

The theory of ecologically unequal exchange (EUE) posits that contemporary international trade facilitates a net flow of resources from the peripheral global South to feed industrial processes and capital accumulation in the core North. This situation, it is argued, imperils the development of the South. Trade is a socio-metabolic process which can be analyzed through systemic aggregate approaches or LCA. Most empirical EUE methods apply the economy-wide systemic approaches. LCA is commonly used to compare embodied resource intensities of different commodities but has not been used to assess EUE. An LCA-based EUE assessment methodology which simultaneously investigates the free-market ideology is developed and tested on trade of Dutch cheese for Kenyan coffee and roses. It has two parts: i) Determination of embodied resource intensity per unit of product and ii) Determination (and comparison) of resource intensity per unit of exchange value. Specifically, the exchange of embodied land, water, energy, CO_2, and labor are examined. The results confirm the EUE theory's hypothesis.

EUE theory remains marginalized in relation to mainstream economic doctrine. To enhance its utilization, the core tenets or claims of EUE theory are synthesized and translated into policy assessment criteria. The key claims are discussed in terms of i) Structure of the capitalist world-economy, ii) Valuation languages, and iii) Equity and justice. The treadmill logic of capitalism in which capital extracts ecological resources and releases waste in an endless pursuit of profits creates an expansionary dynamic which draws peripheral countries into exploitative market relations. This peripheralization is actively supported by 'free-trade' economic theories presented as win-win policies, while states and international politico-economic institutions such as the WTO and World Bank provide the regulations which ensure the proper functioning of the system. Monetary valuation caps it all by obscuring the inverse relationship between thermodynamics and economics in which raw (low entropy) materials are lowly priced while processed goods which have *dissipated* most of their matter-energy (and thus represent high entropy) are highly priced, ensuring that surplus value and resources accumulates in industrialized countries.

The dominant economic conception of the world system is being challenged by a "cultural" perspective which offers a postcolonial critique of the cultural hegemony of the Global North, beyond political economy. I apply this analytic shift to argue that EUE can also be conceived as a social process of *Othering*. Our understandings of economy and the environment reflect past experiences, present preoccupations, socio-cultural assumptions, and specific discursive practices – a *Political Unconscious*. Global environmental politics cannot be understood without considering such assumptions. Conventional hegemonic discourses of neoliberalism and ecomodernism suffer from such a political unconscious. Borrowing perspectives from postcolonial, feminist, and critical social theories, I discuss how Western science exhibit such a political unconscious and their significance for EUE. Ultimately, EUE is a political problem which can only be solved politically.

Key words:

Ecologically unequal exchange, environmental justice, Global South, Global North, international trade, LCA, neoliberalism, political ecology, postcolonial, socio-metabolism, sustainability, science, world-system

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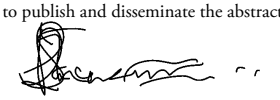
Signature: 

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To the unborn

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Key words:

Capitalism, ecologically unequal exchange, environmental justice, ecomodernism, Global South, Global North, international trade, LCA, neoliberalism, political ecology, postcolonial, socio-metabolism, sustainability, science, world-system

Acknowledgements

A popular statement during my undergraduate days at Moi University in my native Kenya was “degree ni harambee” - loosely translated as “acquiring a degree is a collective undertaking.” This statement perfectly describes the process involved in writing this PhD dissertation. Intellectual wealth is indeed acquired through the accumulation of debt. And I owe a lot of debts.

The biggest debt is to my Supervisor and Head of the Human Ecology Division at Lund University, Professor Alf Hornborg, first for having me admitted to the PhD Programme, and for his guidance throughout the writing of the thesis. The many versions of drafts that he painstakingly went through are testimony. Once while chatting with a friend about my research and how passionate about ecologically unequal exchange Hornborg is, she retorted: “Is he African?” In the modern world in which many intellectuals find it difficult to go against the grain of hegemonic discourses, Alf stands out. The knowing smiles and dismissive chuckles I received whenever I introduced myself as Hornborg’s student have been an inspiration. If a true intellectual à la Edward Said’s (1994) *Representations of the Intellectual* is one who advance marginal perspectives, a disturber of the status quo, speaks truth to power, and bears witness to the oppressed, Alf is definitely one of them. Without his guidance, it is hard to imagine how else this thesis would have turned out. To Alf, Tack You Very Much! I extend similar gratitude to my Assistant Supervisor Professor Pernille Gooch for dedicating her time to read through and help refine the thesis, particularly Paper III. I can only wish to have half her revolutionary spirit when am her age.

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Professors Magnus Jirström and Karl-Johan Lundquist, the two Heads of Department of Human Geography during my tenure as a PhD student warrant special mention. Your open door policy (literally!) and administrative support enabled me to conduct my field work, attend conferences, and conveniently access other support services which I otherwise would not have. The same goes to all faculty and administrative staff of the Division of Human Ecology and Department of Human Geography. I wish to single out Professor Thomas Malm for, on several occasions, giving me the opportunity to share my work with his students. The moral and intellectual support of my colleagues Rikard, Ragnheidur, Andreas, Sarah, Gregory, Sanna, and Marcella is highly appreciated. I am grateful to Lund University and by extension the Swedish Government for generously funding my PhD studies. I am tempted to believe that this is illustrative of a recognition and 'payment' of the 'ecological debt' which is discussed at length in this thesis.

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My family and friends have provided physical, intellectual, and emotional support that I couldn't do without. My wife Faith and daughter Asande have given so much of themselves yet endured so much 'unequal exchange' from me for the period of my PhD studies. You have kept me sane and for that I am eternally grateful. My mother Euniter and sister Millicent have been very dependable 'project managers' while I was away.

Like Descartes would say, I have written this dissertation as if no one had written on these matters before. But I also know that I could only do so by standing on the shoulders of others. In the Preface to *How Europe Underdeveloped Africa*, Walter Rodney (1972:7-8) states that contrary to the fashion in most prefaces, he will not add that 'all mistakes and shortcomings are entirely my responsibility'. To him, "that is sheer bourgeois subjectivism [since] [r]esponsibility in matters of these sorts is always collective, especially with regard to the remedying of shortcomings." I share Rodney's sentiments. Therefore, I take full responsibility for this thesis to the extent reasonably attributable to myself.

Oulu

Lund, April 2016

List of Papers

Paper I: Martin Oulu (2015). *The unequal exchange of Dutch cheese and Kenyan roses: Introducing and testing an LCA-based methodology for estimating ecologically unequal exchange*. *Ecological Economics* 119, pp. 372-383.

Paper II: Martin Oulu (2016). *How can decision makers know ecologically unequal exchange when they see it? Interrogating the assumptions behind conventional policy*. Paper accepted for publication in the Journal of Political Ecology

Paper III: *A philosophy of inequality? Linking ecologically unequal exchange to postcolonialism and science's "political unconscious."* Paper submitted to the Journal of Political Ecology

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1 Introduction

This PhD dissertation is about the theory and phenomenon of ecologically unequal exchange (EUE). EUE theory posits that contemporary international trade is structurally organized in a manner that facilitates a net transfer of resources (matter-energy) from the periphery of the world-system (the Global South) to feed industrial development in the core (Global North). The consequence, it is argued, is environmental degradation, general underdevelopment and poverty in the South but augmented productive capacity and 'development' in the North. Because EUE views money as a fetish which masks unequal social relations of exchange, it chooses to measure exchange in terms of biophysical metrics (e.g. tons, joules, liters, hectares, man-hours, etc.) rather than money. Although EUE can become manifest within a country or within a region, this thesis, inspired by world-systems analysis, will use the analytical categories of North/South. I take the position that as much as China is, for example, emerging as a core for say Africa, it is nevertheless largely a conduit for resources which eventually end up in the world's core of industrialized Northern countries.

I will use the analytical categories of core/ North/ industrialized/ developed/ rich/ First World vs. periphery/ South/ non-industrialized/ developing/ poor/ Third World to distinguish various regions of the world. As such, it is important to problematize their usage. My use of the core-periphery distinction is informed by the dependency tradition and world-systems analysis (see Section 2) which are important theoretical anchors of EUE. The core-periphery division generally posits that there exists an international division of labor in the world-economy such that some sections of the world specialize in 'producing' and exporting raw materials and agricultural products while others specialize in processed goods or manufactures. Obviously these categories are not definitive or clear cut. There are countries in the Global North which largely produce raw materials (e.g. Canada), some in the South are very industrialized (e.g. Singapore), while others like Japan are categorized as 'Northern' but are actually located in the Southern Hemisphere. Some of these categories are also questionable concepts which advance certain hegemonic discourses (e.g. 'developed'/'developing' or 'poor'/'rich') and their usage reinscribes such dominant identities and unequal power structures (cf. Escobar 1995). In fact many of them are simply "imagined communities" (Anderson 1983). However, they have become common terms which are used to describe certain regions and/or conditions in both the academic and policy

arena. I will therefore use them but with the above-mentioned caveats in mind. As Chakrabarty (1992:1-2) notes,

> "Liberal-minded scholars would immediately protest that any idea of a homogeneous, uncontested 'Europe' dissolves under analysis. True, but just as the phenomenon of orientalism does not disappear simply because some of us have now attained a critical awareness of it, similarly a certain version of 'Europe,' reified and celebrated in the phenomenal world of everyday relationships of power as the scene of the birth of the modern, continues to dominate the discourse of history. Analysis does not make it go away."

The thesis examines EUE from an empirical, policy, and theoretical perspective. Comprising a compilation thesis, i.e. a thesis based on peer-reviewed articles (See List of Publications), each of the papers explores different dimensions and impacts of EUE. More importantly, they critically interrogate contemporary conventional discourse (e.g. neoliberalism and ecological modernization) and the scientific theories that back or espouse them. This interrogation is therefore at the core of the thesis and is the inspiration behind the title "Fair Enough?" That is, while the issues of equity, justice, and fairness that EUE raise are quite thoroughly dealt with, an additional aim of this thesis is to critically examine conventional economic, environmental and social discourse and thought from an EUE perspective. This connects with the aim of making EUE more 'user-friendly', i.e. ready to grasp and utilize by policymakers and social movements. This of course begs the question, what do social movements need? There exist many theories and perspectives on why social movements emerge, who joins them, what they do and achieve, and why they decline. But we can infer what they *need* from what they *are*. Social movements, according to Goodwin and Jasper (2009:3), are "conscious, concerted, and sustained efforts by ordinary people to change some aspect of their society by using extra-institutional means." Policymakers can be seen as those who attempt to bring societal change primarily through existing institutional frameworks, but social movements do use such institutions too. Social movements are ordinary people dissatisfied with some aspects of society and who wish to effect some social change in order to rectify their dissatisfaction. Such change can target the power structures, discourses, theories, ideologies, culture, and any other such frameworks which cause or contribute to socio-economic inequality and environmental harm at different scales.

Although the thesis focuses on contemporary discourse, I am aware of and am guided by the dialectical dictum to *always historicise.* Benedetto Croce is famous for stating that "every true history is contemporary history", a reflection of the modern character of history (Butt 2002). A historical, "deep time" or *longue-durée* approach is required to appropriately grasp global phenomena. This introductory essay provides context and background to the published papers, discussing their different points of

departure, their discursive constraints, and embeds them within the general scheme of the thesis and EUE theory.

1.1 Aims and Objectives of the Thesis

This thesis is the result of a 2011 call for a PhD position in Human Ecology at Lund University, Sweden, directed towards ecological aspects of economic accumulation. As such, the aim was to an extent predetermined by the objectives of the call. In line with the general focus of the Human Ecology Division of Lund University on world-systems perspectives on environmental justice, political ecology, and ecologically unequal exchange, a key aim of the doctoral position was "*to develop innovative analytical tools for conceptualizing ecologically unequal exchange in the world-system, and accessible methods of quantifying such resource transfers and environmental load displacements using metrics not normally applied in conventional economics*" (The PhD Call 2011). The PhD research and dissertation was to be oriented toward quantitative aspects of historical and/or contemporary patterns of trade, land use and resource extraction, with an emphasis on non-monetary metrics such as embodied land, energy, and labor time. Equally important was to examine the political ecology of such material and energy distribution. This guiding framework therefore delineated the scope of this thesis. As already outlined above, I chose to focus on contemporary conventional discourse while remaining cognizant of the historicity of the contemporary. I interpreted accessibility to mean 'user-friendliness', able to be easily grasped and utilized by policymakers and social movements.

The PhD research was also part of the Environmental Justice Organizations, Liabilities and Trade (EJOLT) project. EJOLT is an EU funded FP7 project aimed at supporting the work of environmental justice organizations (EJOs) by bringing together scientists, activist organizations, think-tanks and policy-makers from the fields of environmental law, environmental health, political ecology, and ecological economics to engage with issues related to ecological distribution. At the core of EJOLT are the use of the concepts of EUE and ecological debt in science, environmental activism, and policymaking. These aims have significantly influenced this dissertation, particularly the urge to 'simplify' EUE and make it more user-friendly for policymakers and social movements. The EJOLT project, through the various workshops and conferences it organized, not only exposed me to various experts and activists who were part of the network, it brought me into direct contact with some of the communities and environments suffering the consequences of some of the issues discussed in this thesis, and exposed me to some of the grassroots strategies they are employing to resist, from struggles over oil extraction in Nigeria to the political ecology of waste management in Italy. This is not to say that I never had

such experiences before. Being from Kenya, a country located in East Africa, I have seen my fair share of poverty, environmental degradation, and general underdevelopment. But even for me, to see and touch the rivers flowing with oil from oil spills in the Niger Delta, the Ogoni villages deserted because of the resultant environmental degradation, to hear the experiences of women who cannot carry pregnancies to term due to the pollution, was a whole new reality. If at times I come off as activist, militant, or 'revolutionary' in this thesis, feel free to blame it on such experiences.

The analysis of EUE is done from empirical (Paper I), policy (Paper II) and theoretical (Paper III) perspectives. I examine EUE's relation with and implications for, among others, international trade, socio-economic development, environmental justice, and sustainability from a world-systems perspective. The thesis has several key objectives, which I summarize below. However, these were not outlined from the outset but rather guided by the above general framework of the Call for PhD position, developed organically as I got more involved with the EUE literature and as the research progressed. One of my original aims was to develop a novel methodology through which I could offer my own quantitative proof of the occurrence of EUE. This is thus the first objective of the thesis: *To develop and empirically test a new biophysical method for assessing the occurrence of ecologically unequal exchange.* The outcome is Paper I: *The unequal exchange of Dutch cheese and Kenyan roses: Introducing and testing an LCA-based methodology for estimating ecologically unequal exchange*.

Paper I addresses the following:

i) Applies life cycle analysis (LCA) to estimate EUE. Although LCA is a widely used tool and is the basis of many sustainable consumption and production (SCP) policies, it has, until now, never been used in relation to EUE. This paper suggests an LCA-based methodology as a means of assessing the occurrence of EUE and, in so doing, expands the horizon for the application of LCA to EUE.

ii) Demonstrates that and how EUE can be identified at the product level. Most empirical EUE studies take an economy-wide national, regional or global approach, tracking flows of matter-energy at such aggregated levels. Such aggregated studies, though necessary, tend to abstract the EUE concept, a criticism which, unjustifiably, has been extended to world-systems analysis. To my knowledge, no study has ever investigated and compared the international exchange of several environmental resources and impacts embodied in individual commodities.

iii) Investigates a key mechanism through which EUE is kept invisible and therefore sustained – market prices and the free market ideology.[1] Although many empirical EUE studies apply different methodologies to illustrate the asymmetric flow of resources from the periphery to the core, the ideological mystification of such unequal exchange is generally not discussed. By relating embodied resources to exchange value, this study was able to demonstrate that market prices through the free market ideology is the main means through which EUE is reproduced.

One of my concerns regarding the theory of EUE has been its apparent 'underutilization.' Although no study has sought to gauge such knowledge, EUE theory, at least as conceptualized in literature, is not well known beyond the handful of researchers who are interested in the subject, and even less outside academia. It is fair to say that apart from and beyond the use of the concept of 'ecological debt' in the climate/environmental justice movement, EUE theory is little known or utilized. I discuss some possible reasons for the underutilization in Paper II. Such underutilization, I argue, is not necessarily caused by how EUE has been studied. Much of it is due to dominant discourses and embedded power structures which benefit from such unequal exchange and who, therefore, find it in their interest to mask or mystify EUE. But I am convinced that how EUE theory is conceptualized, translated, and presented to those who need it to challenge, resist, or make demands upon the power structures and elites can play a role in dismantling the systemic impediments and bring about the necessary societal change. Challenging hegemonic discourses requires revealing and de-bunking the very premises and assumptions of such discourses.

How can the critical voice of EUE theory be put at the service of or aligned to the needs of social movements and policymakers who wish to change contemporary society dominated by conventional discourses such as neoliberalism and ecological modernization which they assess as not designed to or capable of serving their interests? In this quest, I found community of purpose in the above-mentioned EJOLT project and the outcome is Papers II and III. Paper II synthesizes key claims of EUE which have so far remained scattered. It illustrates how what are often taken for granted as being at the service of all humanity such as capitalism, free trade, monetary valuation, and existing politico-economic institutions such as the WTO, World Bank and IMF in fact combine to create an exploitative world-economy in which resources perpetually flow from the periphery to the core, disenfranchising a majority of the world population, most of who reside in the Global South. By

[1] The core element of an EUE theory is the exchange of more biophysical resources for less (Foster and Holleman 2014). However, any theory of EUE must go further and identify and explain the *mechanism(s)* through which unequal exchange takes place (cf. Hornborg 1998; Martinez-Alier 2002). Market prices and other EUE mechanisms are discussed in detail in Paper II.

breaking down the EUE theory into its basic elements and reassembling them into three simple categories and assessment criteria, it is hoped that EUE theory becomes easier to understand by policy makers and social movements. Moreover, by applying the criteria to a real life policy – the EU's Raw Materials Initiative (RMI) - the partisan interests of such policies which are often presented as scientific or evidence-based, are exposed.

The second objective of the thesis, therefore, is: *To synthesize EUE theory into policy assessment criteria and apply the criteria to a conventional policy*. The outcome is Paper II: *How can decision makers know ecologically unequal exchange when they see it? Interrogating the assumptions behind conventional policy*. The highlights of Paper II are:

i) It breaks the EUE theory into its basic elements and reassembles them into three simple categories. In so doing, it is hoped that it makes the theory more accessible.

ii) Develops assessment criteria for policies from an EUE perspective. To my knowledge, no such assessment criteria have so far been developed. Students, policy-makers and social movements should find this a useful guide in their work, while researchers can modify, adapt and use the framework to conduct more specialized and detailed assessments.

iii) Applies the assessment criteria to a real life policy. This way, the rhetorical nature of the EU's RMI, a representative of conventional policy, is exposed. The recommendations made in the paper are relevant not only to the EU but to all who do business with the EU. The assessment can also be replicated across different policy areas and geographical locations.

Paper III deviates significantly from the current conception of EUE used in the first two papers. Here, I step back from, reflect on, and take a detached look at the theory of ecologically unequal exchange from a postcolonial, cultural, and political perspective. So far (i.e. in Papers I and II), I have taken as given the dominant conception of EUE as primarily an economic or materialist phenomenon.[2] That is,

[2] Arguing that the economy is increasingly becoming people's lens on reality, Norgaard (2009) provides a useful explanation of economism and its link to global environmental challenges. He defines economism as "the mix of popular, political and policy mythology as well as practical beliefs that help us understand and rationalize the economy and how we live within it" (p. 80). Arguing that today economism functions as religions have functioned in history, he categorizes economism into five realms of beliefs which nevertheless cannot be disentangled: academic economism, acculturation of students, professional work of economists, popular political economic discourse on ends and means, and people's everyday empirical evidence of participation in the economy. According to Norgaard, economic theory is not the problem *per se* since most economists clearly outline their assumptions or the conditions under which they apply. Rather, the problem is when these assumptions become generalized and established as *practical* working doctrines while making no sense at all for global-scale challenges and phenomena. Amin (1976) argues that whereas in precapitalist societies economic life is not primarily concerned with commodities, under capitalism the entire economy becomes a

the structure of international trade in the capitalist world-economy is what creates the international division of labor that is EUE and its consequences. This economic conception, I contend, can be traced back to the Marxist analytical framework of a determinant *economic base* and its cultural, political, and other *superstructures*. In Paper III I posit: what if, for argument's sake, we turned the Marxist framework on its head and argued that EUE is primarily political, and that it's 'politicalness' is not supplementary or auxiliary to the economic? Is it possible that EUE is primarily a process of 'Othering' driven by notions of cultural, racial, class, gender and other superiority and power ideologies? To advance this argument, I turn to Fredric Jameson's (1981) notion of a *Political Unconscious* and apply it to the philosophy and practice of Western science. Science is a significant social force which structures contemporary discourse but whose benefits and harms are not always equally distributed.

This epistemological exploration of the theory of EUE forms the third objective of the thesis: *To critically reflect on the epistemology of and embed ecologically unequal exchange theory within the philosophy and practice of science.* The outcome is Paper III: *A philosophy of inequality? Linking ecologically unequal exchange to postcolonialism and science's 'political unconscious'.* Paper III is thus novel in the following ways:

i) This is the first time that EUE scholarship is directly linked to the rich discourse under the banner of 'postcolonial' theory while drawing parallels with feminist theory. This is based on the argument that just like colonialism and gender discrimination, EUE is a social process of constituting the 'Other'.

ii) It provides an alternative basis for addressing EUE. If it is argued that the search for the material necessities for survival is what causes EUE, then it could be presented as morally defensible, at least from the perspective of the dominant group's survival. All that the dominant group needs to say is that it requires the material resources to 'survive' or maintain its 'lifestyle,' and that it did not intend that others should be disadvantaged in the process. George Bush's declaration just before the 1992 Earth Summit that "the American way of life is not negotiable" exemplifies such arguments. If, on the other hand, EUE is conceived as a political project, i.e. the social expression of cultural, racial, gender, or class

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commodity economy, a situation reflected in conventional economic theory through "supply and demand". This theory is supposed to constitute a universal economic science, treating all civilizations as commensurable social forms. In so doing, he adds, economics "loses its scientific character, becoming an ideology" (p.60). Godelier (1972) uses kinship relations to criticize orthodox Marxist vulgar materialism of reducing everything to mere economic relations. Vulgar materialism, explains Godelier, considers the economy – the relations men form among themselves in the process of producing the material conditions of their existence (thus reduced to relations between technology and environment) – as giving rise to society.

superiority, then EUE becomes morally indefensible. This is a much better platform from which the Global South can mount its resistance to capitalism and other power structures which cause EUE.

iii) It significantly changes how EUE is defined, conceptualized, analyzed, and applied. If we accept that the primary motivation or driving force behind EUE are cultural and ideological beliefs in racial, cultural, gender, or class superiority, and that the environmental, economic and other social aspects are a consequence of such dominating identities, then the entire framework upon which EUE has been understood shifts. In this sense, Paper III is paradigm-shifting, at least for the understanding, study, and application of EUE. It rewrites the EUE theory from a postcolonial and cultural perspective.

From the foregoing, it is clear that I do not consider the fact that science contributes to social inequality as novel. This point has been made by a number of postcolonial, decolonial, feminist and critical science scholars. I only use science to advance my argument, while reminding myself that a PhD thesis is an academic endeavor being undertaken within the confines of the philosophy and practice of science. As Harding (2006) puts it, the banality of modern science's contributions to social injustice and inequality is not in doubt since it is the very ontology of science which generates the inequitable effects. It is important to keep this in mind. There are those who find it difficult to comprehend that science can be biased, at times serving the interests of a powerful minority group rather than the common good. To them, science is only 'good' and therefore devoid of issues of interests, ideology, and power. Those who belong to this camp will find Paper III particularly difficult to engage with, but I hope that such a challenge can be overcome.

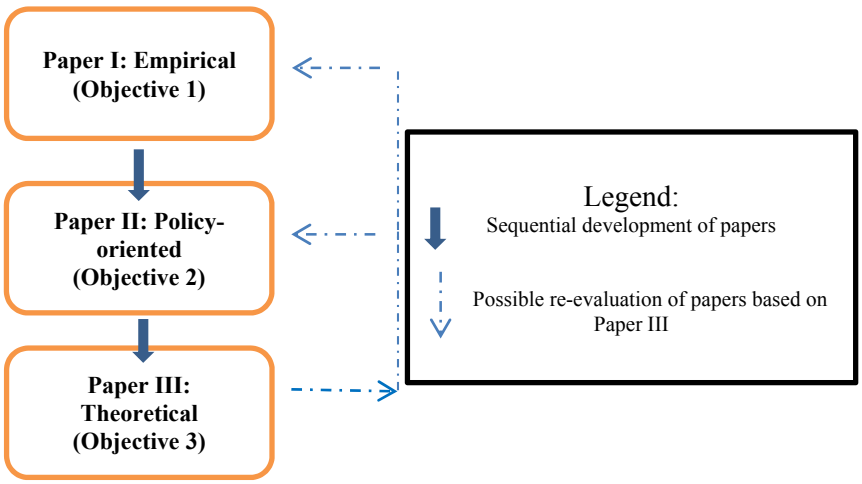

Figure 1.1:
Interconnection between Objectives and Papers

1.2 Organization of the Thesis

The thesis is sequentially organized along the three above-mentioned objectives and related papers (See Figure 1.1). Some may feel that objective 3 (or Paper III) should come first. This is, however, not how I developed the thesis. As already explained, when I began researching on the subject, my immediate concern was to develop and test my own methodology. Once I provided such a methodology (Paper I), I become interested in how EUE theory could be made to assist policymakers and social movements in their struggles (Papers II and III). As such, Paper III should first and foremost be understood as my attempt to enhance the utilization of EUE by re-politicizing it. How such a re-politicization impacts EUE scholarship (if at all) remains to be investigated. The interconnection between the papers outlined above notwithstanding, any of the three papers can be read as standalone arguments. The thesis can thus be read in whichever direction one chooses.

In terms of organization, **Section 1** provides an introduction to the thesis and outlines the objectives and organization of the thesis. **Section 2** discusses the theory of ecologically unequal exchange (EUE) within the broader trade and environment discourse. **Section 3** highlights different approaches and methods of assessing the occurrence of EUE and summarizes the proposed LCA-based methodology. **Section 4** discusses policy-related aspects of EUE, including sustainability, ecological modernization and environmental justice. **Section 5** discusses the sociological concept of *Otherness* followed by a discussion of EUE as a Political Unconscious. It concludes

with a brief overview of the relation between science and inequality. **Section 6** makes concluding remarks.

2 Theory: Trade and Environment

2.1 The Logic of Exchange

International trade is premised on the logic of exchange. The logic of exchange, presented by Adam Smith [1776] (1937) more than two centuries ago in *The Wealth of Nations* when he argued for the benefits of an international division of labor, posits that when two parties who are free to choose decide to enter into an exchange, they do so because it makes each one of them better off, a win-win outcome. This logic was later extended by David Ricardo's [1817] (1951) theory of comparative advantages in his book *On the Principles of Political Economy and Taxation*. It was originally illustrated using a two-production sector, two-country model (wine and cloth in Portugal and England) in which Portugal produced both wine and cloth more efficiently (using less total labor than England), and thus had an absolute advantage over England in the production of both commodities. Nevertheless, Portugal had a comparative advantage in making wine over cloth (it was most efficient in producing wine), while England had a comparative advantage in producing cloth over wine. Under these circumstances, Ricardo argued, both countries would be best off if they each specialized in trading that product in which they were relatively most efficient – in Portugal's case wine, in England's case cloth. A country thus has a comparative advantage if i) it can produce a product at a lower *opportunity cost*[3] than another country or ii) it has greatest productivity advantage or least productivity *dis*advantage. This arrangement, the argument goes, would provide the maximum benefit in terms of the total use values produced, i.e. cloth and wine, for both countries (cf. Love 1980; Suranovic 2010; Foster and Holleman 2014).

The crux of Ricardo's theory of comparative advantages is that the benefits of specialization and free trade still accrue to both participating countries even when a country has no absolute advantage whatsoever. That is, as long as the cost ratios differ between countries in the absence of trade, every country will have a comparative advantage, an ability to find some good it can produce at a lower relative cost than other goods, and that this good should be exported in exchange for some others

[3] The opportunity cost of cloth production is defined as the amount of one product (e.g. wine) which has to be given up in order to produce one more unit of another (e.g. cloth).

(Muradian and Martinez-Alier 2001; Suranovic 2010). In essence, an international division of labor based on efficiency is necessary and trade is preferable to autarky.[4] This was further elaborated by the Heckscher–Ohlin (H–O) theory which states that a country has a comparative advantage in producing and exporting the goods in whose production domestically abundant factors of production are used (Muradian and Martinez-Alier 2001). Those goods which require locally abundant factors of production but little of scarce factors are exported in exchange for those that require factors in the opposite proportions. The H-O model is based on several assumptions such as different endowment with factors of production between the two countries, international immobility but domestic mobility of factors of production (capital and labor), and no externalities in production. Out of the H-O model comes the factor-price equalization theorem which states that as the prices of goods are equalized between countries as they move to free trade, then the prices of the factors of production (capital and labor) will also be equalized between the trading countries and eventually across the world. This theorem implies that free trade will equalize the wages of workers and the rents earned on capital throughout the world (Suranovic 2010). It shares the assumptions of the H-O model, including perfectly competitive markets.

Neoliberalism, the contemporary practice of neoclassical economics, takes these comparative advantage theories and premises to heart, arguing that free trade strategies benefit all. Neoliberalism is a theory of political economic practices that proposes that human well-being can best be achieved through strong private property rights, free markets, and free trade (Harvey 2005). The state under neoliberalism is expected to create, preserve, and defend by force if necessary an enabling environment for such practices, creating and extending markets where they (currently) do not yet exist, but beyond these minimum interventions the state should not venture – the market will decide what is optimum. The benefits of trade, economists argue, are not only limited to economic growth and welfare improvement for all; they also extend to the environment. To them, the only challenge to welfare or sustainability is if 'externalities' are not internalized, i.e. if the 'correct' value or price is not placed on environmental resources, something they argue could still happen under complete autarky – which means that trade is not the problem (Muradian and Martinez-Alier

[4] Autarky is normally construed to mean no trade. However, the Merriam-Webster dictionary defines autarky as self-sufficiency, independence; specifically national economic self-sufficiency and independence, or a policy aimed at achieving such. This is a markedly different understanding and elevates the question to whether international trade is better than national self-sufficiency. The essence of sustainability is living within ecological limits or 'carrying capacity.' In *National Self-Sufficiency*, John Maynard Keynes (1933) argued for minimalization of involvement in international trade, noting that ideas, knowledge, art, hospitality, and travel are the things which should be exported across borders, "but let goods be homespun whenever it is reasonably and conveniently possible; and, above all, let finance be primarily national" (pp. 755-769).

2001). EUE theory disagrees. Raul Prebisch, one of the pioneer theorists of unequal exchange, says that,

> "In economics, ideologies usually tend either to lag behind events or to outlive them. *It is true that the reasoning on the economic advantages of the international division of labour is theoretically sound, but it is usually forgotten that it is based upon an assumption which has been conclusively proved false by facts.* According to this assumption, the benefits of technical progress tend to be distributed alike over the whole community, either by the lowering of prices or the corresponding raising of incomes. The countries producing raw materials obtain their share of these benefits through international exchange, and therefore have no need to industrialize. If they were to do so, their lesser efficiency would result in their losing the conventional advantages of such exchange. The flaw in this assumption is that of generalizing from the particular. *If by 'the community' only the great industrial countries are meant, it is indeed true that the benefits of technical progress are gradually distributed among all social groups and classes.* If, however, the concept of the community is extended to include the periphery of the world economy, a serious error is implicit in the generalization. The enormous benefits that derive from increased productivity have not reached the periphery in a measure comparable to that obtained by the peoples of the great industrial countries. Hence, the outstanding differences between the standards of living of the masses of the former and the latter and the manifest discrepancies between their respective abilities to accumulate capital, since the margin of saving depends primarily on increased productivity. Thus there exists an obvious disequilibrium, a fact which, whatever its explanation or justification, destroys the basic premise underlying the schema of the international division of labour" (UN 1950:1, emphasis mine).[5]

Prebisch contends that Ricardian theory of international trade is based on an assumption that is *false by facts*. In Paper I, I similarly demonstrate that free trade, contrary to the comparative advantages theory, masks EUE in which one partner is consistently disadvantaged. This adds to a number of more aggregate studies which convincingly show that free trade does not benefit all as claimed. But is Ricardian theory theoretically sound as Prebisch suggests? Prebisch, while being diplomatic about it,[6] obviously doubts that it is valid, at least its 'universalization.' In Paper II, I show how, from a thermodynamics perspective, the inequality inherent in capitalist processes combine with the free trade ideology and politico-economic institutions to contradict the neoliberal free trade assumptions. Prebisch's contention that "the community" or society that economic ideology possibly has in mind is a Western one

[5] The *Letter of Transmittal* notes that "…the undersigned Executive Secretary has sponsored the preparation, of a paper on 'The Economic Development of Latin America and its principal problems', which has been written by Professor Raul Prebisch" (p. v).

[6] Not only was he writing for his employer the UN, Prebisch was trained and worked as an economist (cf. Love 1980).

- the industrialized 'developed' countries - is interesting. Is it coincidental? I examine this *Eurocentric* angle to the unequal exchange debate in more depth from a postcolonial, feminist, and critical science perspective in Paper III. Ironically, Foster and Holleman (2014:202) argue, "criticism of colonial practices was part of a general theoretical defense of free trade." Most major contributors to classical political economy such as Adam Smith, David Ricardo, J.S. Mill and Karl Marx, they note, wrote extensively on colonialism and pillage during the mercantilist era of what is now known as the Third World, arguing that the best way to stop such colonial pillage would be to transition to free trade. Such thinking dominates conventional international trade theory and policy today, the belief that under decolonial contemporary free trade, "pillage" or resource appropriation is no more. However, EUE theory demonstrates otherwise.

The United Nations Conference on Environment and Development (UNCED) Agenda 21 illustrates how Ricardo's comparative advantage theory continues to influence contemporary international trade. Section 2.5 states:

> "An *open*, equitable, secure, non-discriminatory and predictable *multilateral trading system* that is consistent with the goals of sustainable development and leads to the optimal distribution of global production *in accordance with comparative advantage is of benefit to all trading partners*" (UNCED 1992:4, emphasis mine).

All actions that are proposed to promote sustainable development through trade as well as in developing countries (this is the focus of Chapter 2 of Agenda 21) is thus premised on comparative advantage theory. However, as indicated above, comparative advantage assumes international immobility of capital, a fact made clear by David Ricardo. If capital is able to cross national borders, then it would seek absolute advantage (profitability) as it does domestically (Daly 1999). That is, capital only has reason to specialize within the country if it is not free to move across borders, and this is the only condition under which comparative advantage theory works. In the modern world, however, capital is highly mobile internationally, sometimes merely at the touch of a button. As capital leaves a country to pursue greater profits (or absolute advantage), Daly argues, then that country loses both capital and jobs and thus becomes worse off. This is also the rationale behind EUE. As resources flow from a country, the country of origin becomes worse off while the one that receives the resources (destination country), i.e. where the capital (and profits) accumulates, is better off. Daly summarizes the irrelevance of comparative advantage in contemporary international trade as such:

> "However valid comparative advantage may be as a logical exercise, it is irrelevant in a world dominated by international mobility of capital in pursuit of absolute advantage. There may be good arguments for free trade, but in a world of international capital mobility, comparative advantage *cannot* be one of them. The confident assertion that an open trading system will benefit all trading partners is utterly unfounded" (Daly 1999:124, emphasis in the original).

Apart from the assumption that comparative advantage benefits all, Agenda 21 suggests that free trade and improved market access for developing countries' exports will "have a positive environmental impact and therefore make an important contribution towards sustainable development" (UNCED 1992: 4). This is part of the neoliberal and ecological modernization discourse that considers free trade and the use of the market to 'internalize externalities' as always good for the environment and people, i.e. as leading to sustainable development.[7] Clapp and Dauvergne (2011) categorize environmental viewpoints into market liberals, institutionalists, bioenvironmentalists, and social greens. *Market liberals* are grounded in neoclassical economics, believing that economic growth and high per capita incomes are essential for human welfare and achievement of sustainable development. They believe open and globally integrated markets promote growth, which in turn helps societies find ways to improve or repair environmental conditions. *Institutionalists*, though lamenting lack of global cooperation as a key source of environmental degradation, share the market liberals' view on how political and economic life on the planet is organized. These viewpoints, according to Daly (1999), support open, free international trade because they consider nation-states as incapable of managing their own affairs without the tutelage of multinational corporations (MTNCs) and

[7] Internalizing externalities generally means 'reflecting' or 'including' environmental harms (pollution, biodiversity loss, etc.) into the price of commodities. It is an attempt to influence people's behavior to consume or pollute 'less' through the use of markets and money as the incentive, an attempt to conserve the environment through payment for ecosystem services (PES). A daunting task indeed because money, a cultural/symbolic 'thing', can never 'reflect' or be equal to the environment which is a biophysical (matter-energy) realm. Understanding this difference requires an understanding of the relationship between thermodynamics and economics (See Section 2.2). Mainstream economics present the human predicament as that of imperfect markets, hence market prices need to be corrected by including all of nature's services, getting the prices right (Norgaard 2009). To accept this 'internalizing of externalities' narrative by implication means accepting capitalism's commodification of nature, something many ecological economists actually do. According to Burkett (2005:8), "ecological economists have strongly criticized neoclassical theory for downplaying natural limits to growth; but the basic neoclassical supply and demand framework, with its underpinnings in marginal utility and marginal productivity theory, is still accepted (with qualifications) by many if not most members of the discipline." Under capitalism, Amin (1976) notes, the entire economy (including the environment) becomes a commodity economy and "this situation is reflected in conventional economic theory, which takes as its point of departure 'supply and demand,' thus presupposing the existence of commodities and the market" (ibid. p. 60). To expect that economic valuation will get us out of the predicament in which humanity finds itself, and for which economism is partly to blame, is one of the illusions of contemporary hegemonic discourses.

multilateral development agencies and "also believe that trade promotes growth, growth helps the environment, the environment helps growth, which in turn helps trade which then helps growth again" (ibid. p.127), a spiraling positive feedback that to them is 'sustainable development.' Such a vision of sustainable development is of course oblivious to the physical limits to growth that thermodynamics puts on the economy (see Section 2.2 below). Esty (2005), somewhat optimistic about solving the trade and environment 'conflict,' summarizes the core environmental concerns of free trade and the counterarguments of free trade advocates.

The above viewpoints also fail to acknowledge a conflict between an international trading system based on free trade and a national policy of 'internalizing externalities.' A country which internalizes environmental costs into its prices will be disadvantaged if it trades freely with one that does not (Daly 1999). Globalization and international free trade, Daly adds, means capital mobility allows production to occur at one end of the world and the market at another, enabling capital to bypass national policies aimed at environmental conservation, redistribution, or population control. National protection of the policy of internalizing environmental costs through tariffs on imports is thus justified 'protectionism' as it is different from protecting an 'inefficient' industry (which is also justified on national sovereignty grounds!). But such a distinction is rarely made under free trade. The General Agreement on Tariffs and Trade (GATT) which was established in 1947 under the neoclassical economic assumption that free trade will improve global welfare, and whose principles are still in force today under the World Trade Organization (WTO), has the 'most-favored-nation' (MFN) as one of its key principles (Clapp and Dauvergne 2011). The MFN principle requires signatories to treat "like products" similarly regardless of the country of origin and/or production process. The market liberals assume that economic growth will raise world consumption levels and wages to those in the developed world that are, on the basis of their ecological footprints, already beyond ecological limits. Daly (1999) notes that while growth for the poor is indeed necessary, a simultaneous reduction in resource consumption by the rich to create ecological room for this growth in the periphery is also necessary. This is the point made by EUE theory when it argues that the resource flows to and prodigious consumption of planetary resources and sink capacity by the rich core reduces the developmental potential of the periphery and therefore has to stop and reverse if global poverty is to be addressed and meaningful sustainable development realized. Conventional trade theory and policy fails to appreciate that while free trade will allow some countries to 'import sustainability' (live beyond their national borders or ecological carrying capacity), all countries cannot logically do this. As Daly (1999:126) puts it, "no matter how much world trade may expand, all countries cannot be net importers of raw materials and natural services." Logically, then, someone has to lose under free trade – it's a zero sum game. So much for free trade benefitting all!

Other negative impacts of free trade relate generally to the lowering of national standards and local or national impacts of globalization, what Daly (1999) terms the erasure of national boundaries for economic purposes and the replacement of comparative advantage with absolute advantage or profits. Global economic integration (globalization) can lead to national economic disintegration and, eventually, social disintegration by reducing government's ability to spend on social programs, difficulty in taxing capital, increases in conflicts over basic norms, and so on (cf. Rodrik 1997). A focus on the national level, through the basic unit of 'sovereignty' or social contract in international relations, can make it difficult to appreciate global environmental challenges which disregard national boundaries.

Bioenvironmentalists, according to Clapp and Dauvergne (2011), are inspired by the laws of physical science and stress the biological limits of the earth to support life – "carrying capacity." Sometimes called neo-Malthusians, they consider the neoclassical economic assumption of infinite economic growth as a key source of contemporary environmental crisis: more growth means more consumption of natural resources and more stress on global sink capacity. The field of *ecological economics* is noted as particularly identifying with this viewpoint. *Social greens*, on the other hand, see social and environmental problems as inseparable. They consider inequality and domination, exacerbated by economic globalization, as leading to unequal access to resources and exposure to environmental harms. Drawing on Marxist thought, feminist and postcolonial theory, social greens point specifically to *capitalism* as a primary driver of social and environmental injustice in a globalized world. Capitalism and its global spread through neocolonial relations between rich and poor countries, they argue, lead to an unequal distribution of global income, power, and environmental problems, and is a threat to the survival of the entire human race. Social greens consider the environmental solutions of market liberals and institutionalists as part of the problem because they assume globalization brings environmental benefits. Instead, they call for a dismantling of current global economic structures and institutions. In their endeavor to empower voices marginalized by the process of economic globalization, social greens, for example, embrace indigenous knowledge systems, arguing that these are equally if not more valid than Western scientific methods.

To a large extent EUE theory embraces many of the viewpoints of the bioenvironmentalists and social greens. As illustrated in Section 4, there are many views on how to achieve sustainability. Three schools of thought on the trade-environment nexus emerge from these viewpoints, each with their reasons why: trade is ultimately good for the environment, trade is bad for the environment, and a third middle point position, viz. managed trade can be good for the environment. This compares with Leveson-Gower's (1997) categories of traditional, environmental and ecological. *Traditional* is essentially neoclassical trade economics which tends to stress the dangers of environmental policy for the trade system rather than the reverse. The

environmental trade approach also starts from neo-classical economics but emphasizes policy inadequacies at the national level and assumes a positive relationship between trade and environmental quality. The third approach, *ecological*, questions the ability of the trade system itself to promote ecological sustainability. While Clapp and Dauvergne (2011:15) are careful not to "leave the impression that any one of these [viewpoints] is the 'correct' view," it is important to sieve through such discourses in order to arrive at which ones are intellectually and practically sensible or 'correct'. People put ideas into practice, Daly (1999: xii) says, "and we all have a responsibility for the correctness of the ideas we advocate."

2.2 Economics and Thermodynamics

One of the key explanations of the occurrence of EUE is a 'difference' in understanding between economics and physics. The economic significance of thermodynamics was first argued systematically by Nicholas Georgescu-Roegen (1971) who considered thermodynamics as "largely a physics of economic value" (p. 276) but which "economists have failed to pay attention to […], the most economic of all physical laws" (p. 280). At its most basic level, the lesson of thermodynamics is that life processes, including economic processes, move in a particular direction (not circular) and involve qualitative change, i.e. feeds on low entropy (Georgescu-Roegen 1975:351). The First Law of Thermodynamics states that energy cannot be created or destroyed; meaning the total energy of an isolated system is constant. It is therefore identical to the law of the conservation of energy or matter (cf. the mass balance principle discussed in Section 3.2). However, the First Law is mechanistic because it does not take account of the distinction between available and unavailable energy, something dealt with by the Second Law of Thermodynamics, also known as the Entropy Law. The Entropy law states that the entropy of an isolated system continuously (and irrevocably) increases toward a maximum or is strictly non-decreasing, i.e. energy is only transformed from more ordered (available) to less ordered (unavailable) forms. A simpler formulation is that heat flows by itself only from the hotter to the colder body (i.e. dissipates), never in reverse. Entropy is the measure of the degree of disorder, randomness, or chaos in a system. It is an index of the amount of unavailable energy in a given thermodynamic system at a given moment of its evolution. As such, entropy-order cannot be divorced from human purposes, i.e. it is anthropocentric. If we interpret orderliness of energy as a measure of its availability or human usefulness, then the Second Law of Thermodynamics implies that all production processes convert energy into less available or less useful forms (Georgescu-Roegen 1971, 1975; Burkett 2005).

Georgescu-Roegen (1975:352) famously stated that not just energy but "matter, too, is subject to an irrevocable dissipation." So concerned was he about the prior neglect of material entropy that he proposed a "fourth law of thermodynamics" based on the inevitability of friction, corrosion, and decomposition. The application of the Entropy law to material production is explained in a two-step manner (Burkett 2005:145). First, production of goods and services requires both energy and materials. That is, economic production is dependent on low-entropy energy and matter. The second step is the inevitable dissipation and dispersal of matter and energy into less ordered and less useful forms. For matter, this is due to wear and tear through organic decomposition and friction. That is why a sustainable society would not be able to rely on recycling alone but would have to reduce its reliance on matter-energy throughput, i.e. dematerialize. Herman Daly (1999) shares the view that terrestrial low-entropy includes matter and energy, both of which place absolute limits on economic production, but he goes further to articulate a vision of a 'steady-state' economy. However, the 'steady-state' notion that a capitalist economy can operate with a quota on its total use of low-entropy matter-energy has been criticized as impossible to realize. This is because in a market economy, production is motivated by profit and therefore must rely on growth. Though rational within the ecological system, the 'steady-state principle' is irrational in terms of profit-oriented market economics since high rates of profit and accumulation usually imply a high throughput of matter-energy due to the high rates of entropy – even in service economies (Burkett 2005:170-171). The same criticism can be levelled against degrowth. Degrowth (downscaling production and consumption) within a capitalist system that has as its single and only objective of making profits is simply untenable.[8] To effectively limit entropic degradation would seem to require an economy not shaped by money as we know it.

In a market system, energy and matter is valued only in terms of their inputs to the production of goods and services that satisfy the wants of individuals. That is, the value of any factor of production or final product derives from its productivity or usefulness in this regard. This same argument is applied to sources of low entropy (raw materials) in general (Burkett 2005:161). And this is where the problem begins – the confusion and conflation of the physical with the economic. Any economic interpretation of 'more and less ordered' or 'available' is by necessity anthropocentric when we are talking about energy or matter. Not even proponents of a thermodynamic understanding of economics are prone to reduce economic processes to purely entropic terms. Rather, they treat low-entropy matter-energy as one

[8] In an attempt to deflect such criticism, some proponents of degrowth question whether the "growth imperative" is indeed a defining characteristic of capitalism (cf. Kallis 2015). Degrowth, however, is much broader than just downscaling production and consumption. It is also a critique of growth, search for alternatives, autonomy or self-limitations, and a re-politicization of environmentalism (cf. D'Alisa et al. 2015).

condition for the production of useful goods and services – with human labor, ingenuity, and tastes also playing essential roles (Burkett 2005). Georgescu-Roegen (1971) contends that the economic world is ruled by the concepts of "purposive activity" and "enjoyment of life," neither of which can be reduced to elementary matter or purely physical variables. Thus there is clearly a discrepancy between low entropy in the physical sense (thermodynamically) versus economic value (utility). That is why Hornborg (1998) argues that in order to assess the occurrence of unequal exchange, we need to analyze the direction of net flows of matter-energy (concrete, productive potential) "but *without* falling into the trap of equating productive potential with economic value" (p. 128, emphasis in the original). He clarifies the necessity for such analytic distinction thus:

> "I believe that it is imperative to maintain an analytical distinction between the material/biophysical and the cultural/semiotic dimensions of exchange. It is very obvious that the 'value' or attractiveness of a commodity for a given consumer hinges on the cultural preferences of that consumer [….] rather than on the investments of labour or energy made in its production, and that the former cannot be reduced to the latter" (Hornborg 2011:77).

The economic process, like any other life process, is irrevocably irreversible in physical terms. The Entropy Law recognizes the qualitative distinction between the inputs of available, low entropy resources and the final outputs of high entropy waste or *pollution*. Mainstream economists' preoccupation with only economic value (utility) neglects the biophysical dimensions of economic processes (Hornborg 2011). For economics, the point is that "the Entropy Law is the taproot of economic scarcity" (Georgescu-Roegen 1975:353). The economic process neither produces nor consumes matter-energy but only dissipates it continuously. Matter-energy enters the economic process in a state of *low entropy* and comes out of it in a state of *high entropy*. Production combines human labor with low-entropy forms of matter and energy to produce useful goods and services, but only at the cost of a one-way conversion of materials and energy from more ordered (and thus more useful) forms to less ordered (and less useful) forms (Burkett 2005:44). Were it not for the Entropy Law, it would be possible to reuse the energy of any energy carrier *ad infinitum* by endlessly transforming it into heat-work-heat-work. As Georgescu-Roegen (1971:278) puts it, without the Entropy Law "a country provided with as poor an environment as Japan […] would not have to keep importing raw materials year after year, unless it wanted to grow in population or income per capita." This statement goes to the root of EUE. Unfortunately, money conflates the thermodynamic and the economic. Even though there is no link between a product's material constitution and its symbolic value, the various dimensions are reduced to a common symbolic standard called money by which they are evaluated and exchanged (Hornborg 2003). Money, unlike low-entropy matter-energy, is quantitatively unlimited and completely

homogenous in that it reduces all differences among commodities to purely quantitative differences. It is also highly mobile, a condition that renders comparative advantage theory mute. Georgescu-Roegen (1975) says that

> "Economists have been insisting that 'there is no free lunch,' by which they mean that the price of anything must be equal to the cost; otherwise, one would get something for nothing. To believe that this equality also prevails in terms of entropy constitutes one of the most dangerous economic myths. *In the context of entropy, every action, of man or of an organism, nay, any process in nature, must result in a deficit for the entire system*" (pg. 354, emphasis in the original).

Therefore, economic processes which are driven and shaped by monetary valuation such as in a capitalist market economy are fundamentally antagonistic to nature. Crises in the conditions of human development, even if induced by capitalism, do not necessarily mean crises of capitalist production. This is because the Entropy Law applies to any given quality of matter-energy available for human production, but capitalist reproduction (economics) in no way hinges on the maintenance of natural resources (Burkett 2005:43). Capitalism's entropic dynamics thus pose a challenge to those who champion the integrity of ecological systems. The most effective answer to this challenge, according to Burkett, is through a critical engagement with the struggles of workers and communities to defend and improve their conditions in opposition to capitalism's exploitation of social labor and nature. That is, instead of capitalist markets, we need non-market systems of egalitarian user rights and responsibilities that respect the communal character of natural resources as a condition of human development within and across generations.

Georgescu-Roegen (1975:352) contends that "whatever the economic expertise of other scientists, economists could not fare continuously well in their own field without some solid understanding of the Entropy Law and its consequences." Let us briefly consider how mainstream economics' complete disinterest in thermodynamics contributes to ecologically unequal exchange. From a thermodynamics perspective, as we have seen, energy and materials are spent or *dissipated* in the production process. Hence, because a product dissipates the matter-energy used to produce it, there is more useful energy and matter in the raw materials than in the final product, which represents a net degradation of matter-energy. But market economics does not reflect this natural law. Amin (1998:213) notes that "no definite law exists that relates economic value and common thermodynamic functions." In fact the 'law' is an inverse one. An inverse relationship exists between productive potential and price, in which the processed final product (representing a sum of less useful matter-energy) is economically priced or 'valued' higher than the raw materials required for its production. Because peripheral countries largely produce low-priced primary resources and the core high-priced processed goods, buying the periphery's raw materials cheaply and selling the processed final product expensively creates profits

and accumulation of surplus value in the core, some of which is used to buy ever more primary products from the periphery, which means the extraction and accumulation continues. To satisfy the increased demand, peripheral countries are forced to intensify natural resource extraction, which ultimately leads to local resource exhaustion, ecological degradation, and socio-economic decline. While attributing the success also to "relatively cheap and efficient labor and the quasi-rent of new technological ideas," Georgescu-Roegen (1971:293) clearly acknowledges EUE as a major reason for Japan's development when he states that "Japan can now operate an impressive industry by paying royalties to the nations from which she imports the low-entropy materials."[9] The inverse relation between economics and thermodynamics has not been correctly represented in eco-Marxist theory focusing on the treadmill profit-maximizing logic of capitalism. This argument is presented particularly in Paper II.

2.3 Ecologically Unequal Exchange: Theoretical Background

When I first heard of the term ecologically unequal exchange (EUE), the first thing that came to my mind was colonialism. My country Kenya was one of the many British colonies and this colonial history made colonialism the most readily accessible representation of EUE to me. I am persuaded that this is the case for many lay people. While the scale and significance of the contribution of colonialism and slavery to the development of the developed world is debatable, it would be unreasonable to deny the historical flow of resources from what is now known as Africa, Asia and Latin America to Europe. In *How Europe Underdeveloped Africa*, Rodney (1972) explores the impact of Africa's colonial heritage on its present development status. Indeed, some liberal political economists criticized the colonial "pillage" of resources from what we now know as the Third World as part of their theoretical defense of free trade (Foster and Holleman 2014). Hornborg (2001:57) distinguish five modes of accumulation, ways through which one can increase one's access to resources. The first and "simplest" category he calls *plunder* and includes "…slave raids, and colonial wars of conquest" (p. 57). The others are merchant capitalism, financial capitalism, undercompensation of labor, and underpayment of resources. The fourth category (undercompensation of labor) also includes coercion or *slavery* (in addition to barter trade, redistribution, and market wages). Hornborg's categorization suggests a hierarchy of modes of accumulation, plunder (and slavery) being 'simpler' because it proceeds against the will of one party, i.e. it does not involve any *cultural persuasion* -

[9] How technology acts as a fetish which masks EUE has been extensively discussed by Hornborg (2001).

an ideology that attempts to legitimize or present the exchange as reciprocal - while the 'complex' rest involve such cultural persuasion (through concepts such as 'tribute', 'wage', 'price', 'interest', etc.) that are supposedly shared by both parties. One could argue that there is no 'exchange' or 'trade' under plunder[10] and that this is the reason why the 'complex' modes of accumulation have been the basis upon which EUE theory as we know it today is premised. However, as I argue in Paper III and Section 5, by discarding the 'simpler' modes of accumulation, at least their underlying motivation of ambivalence or 'Otherness,' we abandon a crucial element through which we can analyze and possibly better understand the other modes of accumulation.

A little explored cultural concept which has significant potential for understanding sustainability in general and EUE in particular is the "Image of Limited Good." This is the cultural perception in many societies, at least subconsciously, that their wealth or good fortune is gained at the expense of someone else. Foster (1965) found such a cognitive orientation in several peasant societies who consider their societies as a closed system, a worldview he termed "Image of Limited Good."

> "By 'Image of Limited Good' I mean that broad areas of peasant behavior are patterned in such fashion as to suggest that peasants view their social, economic, and natural universes - their total environment - as one in which all of the desired things in life such as land, wealth, health, friendship and love, manliness and honor, respect and status, power and influence, security and safety, *exist in finite quantity and are always in short supply*, as far as the peasant is concerned. Not only do these and all other 'good things' exist in finite and limited quantities, but in addition *there is no way directly within peasant power to increase the available quantities*…. Consequently, there is a primary corollary to The Image of Limited Good: if 'Good' exists in limited amounts which cannot be expanded, and if the system is closed, it follows that *an individual or a family can improve a position only at the expense of others*" (Foster 1965:296-297, emphasis in the original).

Foster's 'Image of Limited Good' suggest that not only are peasant societies aware of the physical limits which thermodynamics imposes on socio-economic processes, such limits necessarily mean that socio-economic transactions are by definition zero-sum, that is, to increase one's access to resources in a finite world is to make a claim on those of another. The 'Image of Limited Good' therefore not only points to an innate cultural ability to recognize unequal exchange, its view of society or our Planet Earth as closed and finite rather than an open system has significant implications for sustainability. Those who argue that unequal exchange does not exist may want to re-

[10] Hornborg's categorization of slavery as *undercompensation of labor* is questionable unless one argues that under slavery, the slave got *something in return* for his labor other than the 'maintenance ration' he is given to merely survive in order to work for the master.

connect with their 'lost' peasant roots. Trawick and Hornborg (2015) revisit the 'Image of Limited Good' to argue that today two worldviews are competing for cultural dominance. Foster's traditional "image of limited good" which still influences many peasant societies today assumes that societal 'Goods' are scarce because they are derived from limited low-entropy raw materials from commons which must therefore be shared equitably. The other worldview, promoted by mainstream economists, they term "the image of unlimited good"; it assumes an open system in which, contrary to the First Law of Thermodynamics, people 'create' wealth, "an illusion that conflates the properties of wealth's real and virtual forms while ignoring the economy's extreme reliance on fossil fuels and other nonrenewable resources" (ibid. p.1). Although the 'image of unlimited good' appears to be winning, i.e. dominates mainstream discourse, Trawick and Hornborg (2015:1) argue that a shift back toward the traditional closed-system worldview is indispensable if the global solidarity necessary to limit expanding resource consumption and associated environmental change and socio-economic inequality is to be achieved. Contrary to the mainstream economics' metaphor that the rising tide lifts all boats, Daly (1999:21) contends that unlimited growth has in fact worsened inequality within and among nations since "a rising tide in one part of the world implies an ebbing tide somewhere else." Culturally, therefore, the 'Image of Limited Good' offer us a window through which we can grasp unequal exchange even if we might find it difficult to define.

The theory of ecologically unequal exchange (EUE) is largely Grounded Theory. That is, it is based on observed and systematically analyzed data rather than theory developed *a priori*. Strauss and Corbin (1994) define Grounded Theory as an approach for developing theory that is grounded in data that is systematically gathered and analyzed. Unequal exchange is an asymmetric transfer of some quantity or metric (other than money) by which the productive capacity of one social group is augmented at the expense of that of another, measurable for instance in terms of material volume, energy content, or embodied quantities of energy, labor time, eco-productive land, water, or environmental degradation, effectively a zero-sum game (Hornborg 2003, 2011). EUE theory is thus primarily concerned with examining non-monetary (physical) perspectives on resource flows. In fact, a fundamental dividing line between EUE theory and mainstream economists' view of unequal exchange is whether one chooses to count in money or in nature (Røpke 2001:35). EUE theory attributes such asymmetric resource transfers to the structure of the world-economy. According to Jorgenson and Clark (2009:211), EUE theory is concerned with "how the structure of the world-economy influences unequal material-ecological exchanges, often perpetuating global inequalities and uneven environmental impacts, most of which disproportionately harm the environment and well-being of populations in lesser-developed countries." EUE theory therefore suggests that the structure of international trade influences the observed disproportionate access to global environmental space, and that such unequal access is

substantially predicated upon a country's hierarchical position in the world-system (Jorgenson et al., 2009). Because the global flows of resources and waste are intimately connected to the uneven global flows of capital, processes of uneven development and unequal exchange are inevitably political issues deeply infused with power relationships and questions of justice (Moore 2000).

EUE theory thus has two important aspects to it. First, there is a net transfer of resources (matter-energy) from the periphery to the core of the world-system. Such net resource transfers to the core, it is important to note, are not *occasional* as one would expect under Ricardian comparative advantage where *all* the trading partners supposedly have comparative advantage, but are rather *persistent* over a long period of time, revealing a flaw in the ideal model of a mutually beneficial system of exchange. From a free market economic point of view, trade between developed and developing countries is equal exchange, being trade at market prices. That is, as long as exchange is conducted in monetary terms and prices understood to reflect the rational logic of market forces, a market transaction can never be 'unequal' (Hornborg 2003, 2011). However, as we have shown in Section 2.2, this is due to the conflation by mainstream economics of the biophysical/thermodynamic and the cultural/symbolic through the notion of *money*. Unequal exchange, as Hornborg (1998:128-129) puts it, "emerges from a kind of inverse relationship between productive potential and (economic) value." EUE theory makes the necessary analytical separation by counting in 'nature' and not 'money.' In doing so, EUE theory is able to demonstrate, using various methodologies (See Section 3), that what may be considered equal exchange in monetary terms can be perfectly consistent with an unequal exchange in physical terms. The 'systemic flaws' or mechanisms through which the net transfers occur, including the treadmill logic of capitalism, the free trade ideology, the politico-economic institutions, and of course the above conflation of the physical and the cultural through monetary valuation, are discussed in more detail in Paper II.

The second aspect of EUE theory is logically connected to the first and deals with the *impact* of the net resource flows. That is, the net transfer of resources (productive potential) from the periphery to the core (and the simultaneous displacement of environmental burdens from the core to the periphery) limits the developmental potential of the periphery as it augments that of the core. Because "ecosystem services" directly contribute to the achievement of various components of human well-being (Millennium Ecosystem Assessment 2005),[11] the disproportionate

[11] The Millennium Ecosystem Assessment (2005) defines ecosystem services as the benefits human beings derive from ecosystems. They are categorized into *provisioning services* (e.g. food, water, timber, and fiber); *regulating services* (regulation of climate, floods, disease, wastes, and water quality); *cultural services* (recreational, aesthetic, and spiritual benefits); and *supporting services* such as soil formation, photosynthesis, and nutrient cycling. They underscore that while the human species might be buffered against environmental changes by culture and technology, it is fundamentally dependent on the flow of ecosystem services.

consumption of global environmental space by industrialized countries conceivably limits the present and future utilization opportunities of less developed countries (Rice 2007:1369). For this reason, the EUE phenomenon is viewed as being about the environmental and human well-being consequences of the structure of international trade (Jorgensen et al. 2009:266). This second aspect of EUE is what primarily informs the *moral*, equity and justice claims rather than the first aspect. Hornborg (2003:8) summarizes the two aspects of EUE theory in the following statement:

First aspect:

> "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 quantity or metric (other than money) 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,"

Second aspect:

> "…but can of course *inspire* a moral argument when articulated with the observation that an asymmetric transfer (net import) of energy to one region or social group is the basis of a self-reinforcing accumulation of technological superiority and power visá-vis other regions or social groups."

The historical evolution of the concept and theory of unequal exchange has been the focus of a PhD thesis at my department here at Lund University (see Brolin 2006). Brolin attributes the first possible formulation of *ecological* unequal exchange to Arghiri Emmanuel. This he bases on Emmanuel's (1974) contention that apart from exhaustion of deposits and reserves, ecological limitations (which he conceived as a 'full' sea and atmosphere) are other factors which rule out the equalization of consumption upwards, i.e. to the level of the rich advanced countries. In this sense, Brolin concludes,

> "Emmanuel's theory of unequal exchange is essentially a theory of the economic consequences and political implications of the non-equalisability of global remunerations expressed in physical terms. If this formulation qualifies as an 'ecological unequal exchange', it is the first, and indeed *only*, of its kind to be the expression of an actual economic *theory* – aimed primarily at explaining historical developments" (Brolin 2006:202).

Brolin admits that Emmanuel's ecological examples (and theory?) "is not breathtaking" even if "he drew – or confirmed – all the basic political conclusions of

many a radical ecologist or believer in global solidarity of his day" (ibid. pg.202). It is doubtful if Emmanuel's considerations of the environmental aspects of (economic) exchange can be said to constitute a theory of *ecologically* unequal exchange. He is more known for enhancing the *unequal exchange* theory through the labor theory of value (see below). Contrary to Brolin, I attribute the roots of EUE theory to Karl Marx's 'metabolic rift.' That is, I consider Marx's 'metabolic rift' as at the very least a *primordial* or *rudimentary* attempt at describing unequal exchange of nutrients and material (which are ecological) resources between the country and town in nineteenth-century Europe. Brolin quotes Foster's (2000) reference to Marx having borrowed the concept of a 'metabolism (*Stoffwechsel*) between man and nature' from Justus von Liebig but does not consider it germane to a discussion of *ecologically* unequal exchange.[12] Marx (1981, Vol. 1) considered commodity exchange or trade as a "process of social metabolism" (p. 198), that is, the production and exchange of commodities is both a social (between people) and metabolic (between people and nature) relation (see Section 3 for more on social metabolism). In his analysis of commodities and money, Marx emphasized that "the physical bodies of commodities, are combinations of two elements, the material provided by nature, and labour" (ibid. p. 133). This can be interpreted as recognition of the biophysical (matter) *and* labor components of products, seemingly contrary to the labor theories of value of the time.[13]

[12] John B. Foster's attempt to 'ecologize' Marx (eco-Marxism) is not without controversy. Martinez-Alier's (1987) analysis is widely considered the basis of the critique of Marx as paying too little attention to ecology (cf. Hornborg 1998; Burkett 2005). Based on "the Podolinsky business," Martinez-Alier and his disciples suggest that Marx (and Engels) "would not listen" to or treat seriously Sergei Podolinsky's proposal to them to bring natural science (thermodynamics) into their theories on surplus value. However, Burkett (2005) rejects such claims and seeks to show that "Podolinsky had not even come close to establishing a plausible thermodynamics basis for the labour theory of value" (p. 178). This leads him to conclude that Marx and Engels "appreciate[d] the significance of energy and the first law of thermodynamics, while rejecting energy-reductionism in favour of a socio-metabolic and entropic conception of industrialization, environmental crisis, and the necessity of socialism" (p. 175). A major criticism of Foster and colleagues' eco-Marxism project is that they refer to and discuss EUE in terms of asymmetric flows of 'values'/'use values' (cf. Foster and Holleman 2014) which as we discussed in Section 2.2 confuses physics and economics (cf. Hornborg 2015). Such critiques of using 'value' to define EUE are, however, not a rejection of Marx's 'metabolic rift' and/or its possible socio-metabolic and entropic understanding of exchange.

[13] Labour theories of value (LTV) attribute the economic 'value' of a product to the amount of *labor* that has gone into its production, effectively ignoring the material components or physical inputs of commodities. Applied to unequal exchange, LTV would mean the following: "If *unequal exchange* means, ultimately, the transfer of some of the surplus of one area to a receiver of surplus in another, this is the consequence of the fact that more labour power has gone into producing the value exchanged in one area than in the other" (Wallerstein 1982:94). Generally, "theories of value" are reductionist in the sense that they do not analytically separate the material (thermodynamic) and the cultural/symbolic 'attractiveness' of a commodity. That is why Hornborg (1998, 2015) argues that any discussion or reference to EUE in terms of 'value' should be discarded to avoid this confusion and conflation.

Marx's 'metabolic rift' primarily refers to his concern with how, in nineteenth-century Europe, large-scale industry and agriculture under capitalism combined to impoverish the soil (environment) and the worker through the growing asymmetric exchange of nutrients and other material resources between town and countryside, augmented by long-distance trade (Foster 1999; Foster and Holleman 2014; Clark and Foster 2010; Burkett 2005). Inspired by Liebig's analysis in the late 1850s and early 1860s of the problems of capitalist agriculture in which, *i*) the soil was "robbed" of its nutrients through constant farming without restitution, resulting in a decline in the natural fertility of the soil, and *ii*) the products (constituent elements of the soil) were shipped through long-distance trade to distant markets far removed from their centers of production, making it even more difficult to improve local soil fertility through waste recycling, Marx developed his systematic critique of how capitalist agriculture exploited both the soil and the worker (Foster 1999:378-379). With the transition to capitalism, a new division of labour between town and country took shape regionally and on a world scale whereby the products of the countryside flowed into the cities which were under no obligation to return the waste products to the point of production. In essence, the land was exploited until it became unprofitable at which point economic contraction forced capital to expand to and exploit new territories (Moore 2000:124). 'Metabolism' described the *material exchange* between city and country through human labor while the 'rift' highlight the material estrangement of human beings in capitalist society from the natural conditions of their existence, a result of the simultaneous growth of large-scale industry and large-scale agriculture in which industry provided agriculture with the means to intensify the exploitation of the soil (Foster 1999). The metabolic rift was also evident internationally: "For a century and a half, England has indirectly exported the soil of Ireland without much as allowing its cultivators the means for making up the constituents of the soil that had been exhausted" (Marx 1976, p. 860 as quoted in Foster 1999, p. 384). If we apply a world-system perspective to Marx's analysis in the contemporary world by considering the agricultural 'country' to be the peripheral global South and the 'town' as the industrialized core Northern countries, it is reasonable to view Marx's concept of 'metabolic rift' as an embryonic form of a theory of ecologically unequal exchange.

In the 1930's and 1940s, Raúl Prebisch formulated a core-periphery thesis suggesting that the world economic system was a hegemonic hierarchical relationship, something many economists still find difficult to accept today (Love 1980). Some hold that he founded the theory of unequal exchange (cf. Amin 1974; Love 1980). He and his colleagues at the United Nation's Economic Commission on Latin America (ECLA) found a striking empirical pattern in which the terms of trade for primary products (produced by Latin America) consistently declined vis-à-vis manufactured goods (produced by industrialized core Western countries) over time. He attributed this to income inelasticity of demand for primary products, monopolistic tendencies by the industrialized countries, and poor labour organization in the periphery (UN 1950,

1963; Love 1980; Kohler and Tausch 2002; Pérez-Rincón 2006; Foster and Holleman 2014). Love (1980:55) states that in 1948, "Prebisch specifically attacked the theory of comparative advantage, and noted that its precepts were repeatedly violated by the industrialized nations, whose economists nonetheless used classical trade theory as an ideological weapon." In the same year, while teaching in Buenos Aires, he further implied that industrial countries acted as monopolists against agricultural countries, and stressed that the fruits of technical progress, contrary to the equalization claims of comparative advantage theory, tended to remain in the core (then Britain and the US). He suggested rapid industrialization, import substitution (inward directed development rather than export-led growth), and international agreements for price protection for primary products as a solution to these challenges. He elaborated most of his already developed ideas in the ECLA publication *The Economic Development of Latin America and its Principal Problems* (published in Spanish in 1949; see UN 1950 for the English version), most of which were confirmed by the UN Department of Economic Affairs (1949) study *Relative Prices of Exports and Imports of Underdeveloped Countries*. As Love (1980:46) notes, "much of Prebisch's reasoning was based on empirical observation and experimentation."

One year after Prebisch's ECLA (1949) publication, Hans Singer (1950) published an article in which he argued along the same lines as Prebisch: technical progress in manufacturing led to a rise in incomes in developed countries but production of raw materials and agricultural products in underdeveloped countries saw a fall in prices. His explanations that this was caused by different income elasticities of demand and "absence of pressure of producers for higher incomes," a likely reference to lack of labor organization in the peripheral countries, are similar to Prebisch's. For this reason, the two men's theories were quickly dubbed the Prebisch-Singer thesis, even though

> "both economists state that there was no direct exchange of ideas at the time the related sets of propositions, based on the same U.N. data, were developed. (Prebisch of course was in Santiago, and Singer in New York.) Since ECLA's Economic Development appeared in print in May 1949, more than six months before Singer presented his American Economic Association paper (published in 1950), Prebisch clearly seems to have reached his position earlier than Singer; in fact, the U.N. study simply bolstered conclusions he had already reached" (Love 1980:58-59).[14]

[14] Other authors give a different account of who was first and thus whether the thesis is Prebisch-Singer or Singer-Prebisch (cf. Brolin 2006; Toye and Toye 2003; Hermele 2012). This tug-of war is not an idle one. It is illustrative of the politics of knowledge in which scientific theories and knowledge production also subscribe to a core-periphery dynamic which I discuss in more detail in Paper III. Whether the ideas originate from the periphery (in this case represented by Prebisch) or core (represented by Singer) is as important as the ideas themselves. Brolin (2006) states that Prebisch was "more concerned with formulating policy than pure theory" (p. 98), forgetting that Prebisch taught at various universities and policy proposals can form theories or be analyzed as such (see Paper II).

Prebisch's thesis was primarily that of *economic* unequal exchange. However, its contribution to ecologically unequal exchange (the two are often difficult to separate because underneath any 'economic' exchange are biophysical resources) is significant in several ways. First, he put forth a core-periphery thesis (a hierarchy in a unitary economic system) in the contemporary world economic system. His core-periphery thesis covered a large geographical part of the modern world (Latin America – Britain – US), hence, in a sense, Prebisch expanded Marx's European country-town analogy to the entire world. Second, he challenged Ricardo's comparative advantage theory which was (and still is) the main theory advocating and influencing international trade. His arguments for doing so remain relevant to EUE, e.g.;

i) Even though he did not use physical metrics, he identified the long-term deterioration of the terms of trade of agricultural products and raw materials from Latin America vis-à-vis industrial manufactures from Britain and US as a mechanism through which unequal exchange occurs. We can now better explain this through the inverse relationship between thermodynamics and economics rather than his use of the questionable income inelasticity of raw materials economic theory (see below).

ii) He clearly identified the role that politico-economic institutions play in influencing international terms of trade to the disadvantage of the periphery.

iii) He recognized technology as a possible cause of unequal exchange but failed to explain how it does so through, for example, Hornborg's (2001) perspective on technological fetishism.[15]

The industrialization and import-substitution proposals which Prebisch offered developing countries are still valid today under the capitalist system. His analytical terms and associated theory of trade relations, now known as *unequal exchange*, were adopted by the dependency theory tradition and even beyond. Dependency theory is a neo-Marxist explanation of development processes which focuses on understanding the "periphery" by examining core-periphery relations (Sorinel 2010:221). It challenges development theories such as Rostow's (1960) which assert that all societies

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Brolin also argues that Prebisch's "perspective was Latin American, universalising primarily from his native Argentina" (p. 99), while in contrast Singer's perspective is somehow different because it "sprang from concern with distributive justice and was closer to the idealist superstructure of Truman's Point Four program for U.S. foreign investment" (ibid.). According to Brolin, therefore, Prebisch's "Argentinian" perspective is "Latin American" while Singer's "U.S" perspective is universal. How ironical!

[15] By 'machine fetishism' Hornborg (2001, 2009) means that the modern concept of 'technology' is a cultural category referring to what is technically feasible but which is oblivious to the fact that a local increase in technological capacity is a matter of shifting resources from one social category to another. In other words, the apparent generative capacity of machine technology can serve to conceal unequal relations of exchange which only biophysical metrics can reveal. Machine technology, therefore, is not based merely on know-how but more fundamentally on unequal exchange.

progress through similar stages of development, and is predicated on the notion that states are integrated into the world-system in such a way that resources flow from a "periphery" of poor and underdeveloped states to a "core" of wealthy states, enriching the latter at the expense of the former (Velasco 2002:44). The essence of the *dependistas'* argument is that the game of global capitalism is fixed in terms of a predetermined division of labor and exploitative terms of trade, the net sum basically zero. Many contemporary critiques of global capitalism spring from dependency theory.

Some have criticized Prebisch's attempt as unsatisfactorily mixing arguments from demand, costs, and rigidities of wages (cf. Brolin 2006). Indeed, some of his (and Singer's) analyses fall short of explaining EUE because they are based on uncritical economic theories. For example, the idea that raw materials and agricultural products have an income *in*elasticity of demand is incorrect. Income *in*elasticity of demand means that as income rises, demand for certain goods either remain constant or decline (cf. Fuchs 1965). In economics, goods which satisfy such a condition are called *inferior* goods. While possibly true for microeconomics, such inelasticity of demand do not apply at macro levels such as in international trade. We know that as national per-capita incomes rise, consumption generally goes up since people have more disposable income to spend, and spend it by intensifying consumption of goods (superior or inferior) which necessarily require raw materials (low entropy) to produce, whether domestically and/or as imports. This is what economists call economic growth.

Dependency theory greatly influenced *world-system analysis*, a major theoretical anchor of EUE theory. World-systems analysis postulates that national development cannot be understood in isolation from the global system where relatively few nations wield great economic and military power (Roberts and Parks 2007, 2009). A world-system is not a political entity, although it encompasses within it empires, cities, and nation states. The basic linkage between the parts of the system is economic, although this is reinforced to some extent by cultural links and political arrangements (Wallerstein 1974). World-systems analysts view a capitalist world-economy as marked by an axial division of labor between core-like and peripheral *production processes* which result in an unequal exchange favoring those involved in core-like production processes. Core-periphery is thus a relational concept based on the degree of profitability of the production processes, the degree to which surplus-value or profit is disproportionally appropriated by the core (Hopkins and Wallerstein 1982; Wallerstein 2004). Wallerstein proposed four different categories into which all regions of the world can be placed: core, semi-periphery, periphery, and external arena, the core and periphery being of greatest importance since they are geographically and culturally opposed, one focusing on labour-intensive and the other on capital-intensive production. The core-periphery relationship is structural, with semi-peripheral states acting as a buffer zone between core and periphery (Sorinel

2010). Andre Gunder Frank (1967, 2008) similarly describes a global, national and local metropolis-satellite relation in which each satellite serves as an instrument to appropriate economic surplus from its own satellites and to channel part of this surplus to the world metropolis, centered in Europe and the US. In contrast to the world metropolis, which is no one's satellite, the development of the satellites (peripheries) is limited by their satellite status. Although world-systems analysis began by analyzing the world through an economic lens, it has recently become popular in other areas such as literary studies. Eatough (2015) traces literary studies' earliest engagements with world-systems theory to i) the Subaltern Studies project, which analyzed and considered intellectual production as the result of the international division of labor, and ii) Fredric Jameson's Marxism, which sought to map literature onto the world-system. Such *culturalization* of world-systems analysis, which one can view as part of the broader *ontological turn*, is the foundation of my argument in Paper III for a re-conceptualization of EUE as a social process of constituting the 'Other'.[16]

The concept of Global Value Chains (CVC) is probably the approach within neoclassical economics which comes closest to world-systems analysis. It is worth mentioning briefly, as its orientation is diametrically opposed to that of EUE. GVC originated from dependency and world-systems theories but later separated from them (cf. Fernandez 2014; Neilson 2014; Henderson et al. 2002). It seeks to understand the changing nature of international trade and industrial organization through the notion of a value-added chain - the process by which technology is combined with material and labor inputs, and processed inputs are assembled, marketed, and distributed (Gereffi et al. 2005). GVC is primarily concerned with how *a firm* manages its relationship with other firms and positions itself globally in order to make the most profits, and explains how global production might be organized (through markets or within transnational firms) through *transaction cost economics.*[17] GVC evolved from global commodity chains in the 1990s and was an attempt to operationalize some of the world-systems categories for the empirical study of cross-border, firm-based transactions and their relation to development (Henderson et al. 2002). However, and this is where the big split happened, GVC

[16] The Subaltern Studies Group/Project refers to one of the subdivisions of postcolonial theory launched in the 1980s by a group of Indian scholars (cf. Louai 2012; Morris 2010). The 'ontological turn' can be defined as "a commitment to an immanent politics of permanent conceptual differencing" (Candea 2014:1), the "dual movement towards, on the one hand, exploring the basis of the Western social and intellectual project and, on the other, of exploring and describing the terms in which non-Western understandings of the world are grounded" (Course 2010:248). It is the conviction that there are multiple realities (ontologies) rather than just many perspectives on a single reality, something that goes against Western scientific tradition. For more on the ontological turn see Martin and Heil (1999), Sismondo (2015), Pedersen (2012).

[17] Transaction cost economics deals with firm strategy, primarily how firms can minimize transaction costs, i.e. expenses incurred in the process of buying and selling.

"broke with the static (and now empirically redundant) spatial categories of the core/semiperiphery/periphery typology and, as such, was better able to grasp the reality of the 'new' forms of industrial organization that had become the objects of scholarly attention during the 1980s and 1990s" (ibid. p. 440). Proponents of GVC and the related Global Production Networks (GPN)[18] obviously have little admiration for world-systems analysis (and I would guess EUE) which they consider "static" and "empirically redundant." They distinguish themselves by not focusing on the nation-state and criticize world-systems analysis as an analytical framework that promises to address some of the challenges of GVC but which is yet to act as a significant guide to empirical work on contemporary problems of development (Henderson et al. 2002:437). This, they argue, is because the nation-state continues to be the conventional unit of analysis yet exclusive attention to this level of aggregation is becoming less useful in light of the changes occurring in the organization of economic activities "which increasingly tend to slice through, while still being unevenly contained within, state boundaries" (ibid. p. 437).[19] I sympathize with the 'abstract' or 'aggregation' criticism of world-systems theory and EUE approaches, and I attempt to address this challenge by using LCA and focusing on individual products in estimating EUE (see Paper I), but the focus of GVC on conventional economics' concern with money and economic value (surplus value and economic rent) rather than biophysical flows is in sharp contrast with EUE. Nevertheless, GVC has been embraced by major international development agencies. An important moment in the emergence of an implementation-ready 'value chains for development' discourse was a workshop held at Bellagio, Italy, in 2000, sponsored by the Rockefeller Foundation, with the workshop papers published in a special issue of *IDS Bulletin* (Neilson 2014). That 'commodity chains' had its roots in 'fatalistic' structuralist development economics, Neilson argues, was the death knell of GVC's anti-capitalism as mainstream economics scholars sought to play down these critical intellectual influences.

This explains why GVC is now deeply embedded in mainstream economic thinking. For example, applying the GVC framework, Gereffi et al. (2005) correctly note that the epicenter of export-oriented apparel production has been East Asia, but they argue that the key to East Asia's success was to move from captive value chains – i.e., the mere assembly of imported inputs, typically in export-processing zones – to a more domestically integrated and higher-value-added form of exporting broadly known in

[18] GPN seeks to "systematically conceptualiz(e) the *causal drivers* of global production networks in terms of their competitive dynamics (optimizing cost-capability ratios, market imperatives, and financial discipline) and risk environments" (Yeung and Coe 2015:29). See also Henderson et al. (2002).

[19] They mischaracterize world-systems analysis as focusing on the state when in fact "world-systems analysis meant first of all the substitution of a unit of analysis called the "world-system" for the standard unit of analysis, which was the national state" (Wallerstein 2004:16). Wallerstein highlights and responds to four key critiques of world-systems analysis (ibid. pp. 19-22).

GVC parlance as full-package supply (shift from captive to relational value chains). Such "value-addition" arguments are mainstream economics' explanation of what under EUE would be the peripheralization of East Asia due to capital's expansionist quest for "cheap" labor and raw materials, resulting in environmental load displacement from the core. Little wonder, then, that GVC/GPN and the policy prescriptions they inspire have been criticized as nothing more than neoliberal accumulation strategies which promote and facilitate the enhanced penetration of multinational capital and companies into the economy and lives of the rural and urban poor (cf. Fernandez 2014; Werner et al. 2014; Neilson 2014). Fernandez (2014) argues that the supranational institutionalization of GVC has contributed to the legitimation of a subordinated and exclusive pattern of integration to networks governed by the transnational fraction of capital rather than being a tool to genuinely empower developing countries. To him, this has been made possible through the transformation of the GVC into a neoliberal device for strategies implemented by global political networks, and the uncritical assimilation of GVC by these global politico-economic networks. The only point of convergence between GVC/GPN and EUE is, in my view, their mutual concern for global flows, albeit in different ways (economic 'value' for GVC/GPN and matter-energy for EUE).

Arghiri Emmanuel (1972) elaborated Prebisch's core-periphery theory by arguing that developing countries tend to exchange a larger amount of their labor for less foreign labor. In his seminal book *Unequal Exchange: A study of the Imperialism of Trade*, taking the labor theory of value (LTV) as his point of departure, Emmanuel argued that wage differentials (and rates of surplus value) are the root cause of unequal exchange. As already discussed above, LTV ignores the physical inputs of commodities while 'theories of value' do not analytically separate the material (thermodynamic) and the cultural/symbolic 'attractiveness' of a commodity, which makes them unsuitable for discussions of EUE.[20] Nevertheless, Emmanuel's 'narrower' conception of wage-based unequal exchange was rooted in the international mobility of capital, international immobility of labor, and the international equalization of profits (Foster and Holleman 2014). We thus see in Emmanuel a disagreement with some elements of comparative advantage theory (e.g. international immobility of capital) and support for some (e.g. international equalization of profits, as elaborated by the factor-price equalization theorem). In fact, some attribute the term "unequal exchange" to Emmanuel and his attempts to refute the Ricardian notion that international trade is beneficial to both parties (Wallerstein 1982:92). His contribution to the theory of unequal exchange notwithstanding, Emmanuel's conception has been accused of being less historically relevant by disregarding colonialism, plunder, and monopoly. Choosing to focus his analysis only

[20] See Amin (1976) for a review of Emmanuel's theory of unequal exchange, including three types of criticisms to it and Amin's response to them (p. 138-154).

on 'free trade', he states: "As for the actions of the monopolies, of which the Marxist authors talk so much, this question is as remote from our subject as any other form of direct plunder of the underdeveloped countries by the rich and strong ones" (Emmanuel 1972:93). Prebisch highlighted the monopolistic tendencies of the core as important in the inequality of the world economic system. According to Foster and Holleman (2014), Emmanuel's goal was to demonstrate the existence of unequal exchange *even* under free-trade conditions. Hence, they argue, "Emmanuel's rejection of monopoly and plunder as factors … made his theory less historically relevant, and led to a shift toward a more realistic, if less logically tight, theory of unequal exchange" (ibid. p. 204). Emmanuel thus narrowed unequal exchange to merely monetary trade. In Paper III, I contest Foster and Holleman's (2014) apparent suggestion that issues of "plunder," if looked at from the perspective of colonialism and its mission of 'civilizing' the Other, have been adequately tackled by current "more realistic" EUE scholarship.

From Emmanuel, Stephen Bunker (1985) expanded the theory of unequal exchange by arguing that there was unequal transfer of not only labor but also energy and matter from the periphery to the core, and that this affects the subsequent developmental potential of the periphery. In essence, Bunker argued that the use of labor as the standard measure of 'value' for unequal exchange (the LTV) ignores the exchange inequalities inherent in extractive economies where 'value' in nature is appropriated in one region and labor value incorporated in another. Bunker was thus a turning point as he formulated what can be seen as the first concept of *ecologically* unequal exchange by inserting 'ecology' into earlier theories of unequal exchange based exclusively on the labor theory of value. Some commentators have argued that Bunker advanced a theory of unequal exchange based only on "energy values" and therefore did not offer a theory of 'ecological' unequal exchange (cf. Hornborg 1998, 2003). While it is true that Bunker used the contested term 'value' to refer to unequal change and thus fell victim to 'energy' reductionism,[21] he, unlike the LTV camp, used 'value' to refer to both "value in nature" (meaning matter-energy) and "labor value" (a reference to the LTV camp's preoccupation only with labor). Not only that, Bunker was well aware of the Laws of Thermodynamics and their link to unequal exchange.[22] In this regard, Alf Hornborg's (1998) elaboration of the need to assess the

[21] He equates energy (and matter) measures with monetary measures, in effect reducing/conflating the biophysical and the cultural. He states that the concept of value must include anything affecting the reproduction of society, and that "Labor value, or its imperfect monetary measures, cannot do this. Measures of energy and matter and of their conversion, however, touch everything which is humanly useful" (Bunker 1985, p. 35). He is thus arguing that energy and matter are better measures of 'value' than money.

[22] Bunker (1985) states that "I saw that the differences between extractive and productive (industrial) economies were more fully accounted for by the laws of thermodynamics than by the theories of politically enforced unequal exchange. Production involves the *transformation of matter and energy*, neither of which can be humanly created. They must therefore be extracted from a physical

occurrence of EUE by analyzing the net flows of matter-energy (productive potential) but *without* equating it with economic 'value' (utility) is a significant conceptual enhancement of EUE theory.

Using the ecological footprint (EF) measure, Andersson and Lindroth (2001) distinguish three types of 'ecologically unequal' (net EF) or 'unsustainable' exchange (a continuous reduction of ecological capital in at least one of the trading partners) between nations. Simple ecologically unequal exchange, they argue, occurs when country A imports more biocapacity from B than it exports to B.[23] Despite this type of inequality, they add, trade between A and B may be *ecologically sustainable* if neither country runs up an ecological deficit. The key word here is 'ecologically sustainable,' meaning that socio-economic and other considerations are not being taken into account. What I find odd is that Andersson and Lindroth (2001) seem to justify such a 'simple' EUE as 'natural' *if it is based on a technology differential*. What they describe as simple EUE between raw materials-exporting and manufactures-exporting countries (see below) is to a large extent what is going on now between the global South and the global North. But how does a country only armed with 'know-how' and 'innovation' but no material resources (low entropy), somehow magically transform their 'know-how' into material accumulation? Andersson and Lindroth are trying to convince us that it is possible to create *something* out of *nothing*, a view they share with many mainstream economists (and ecomodernists) who frequently talk about wealth "creation". However, as the Laws of Thermodynamics tells us, matter-energy can neither be created nor destroyed, only transformed. Andersson and Lindroth fail to distinguish between "real wealth" (material goods) and "virtual wealth" ("finance capital" - abstract wealth such as bonds, securities, paper money, and digital assets etc.) when they interchangeably use these concepts (cf. Trawick and Hornborg 2015). The paper by Andersson and Lindroth was published in the same year as Alf Hornborg's (2001) book elaborating how machine technology is a fetishized product not primarily of know-how but rather of unequal exchange in the world-system. This is what they say:

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environment" (p. 12, emphasis mine). While Bunker seems to downplay the role of "politically enforced unequal exchange," I am convinced that it plays a significant role in the form of the gate-keeping services which politico-economic institutions such as the WB and IMF offer to the core at the expense of the periphery, an argument I advance in Paper II.

[23] The second type, 'unilaterally unsustainable exchange,' occurs when Country A is a net-importer of biocapacity from B and the natural capital of B is deteriorating. Finally, 'mutually unsustainable exchange' happens when both A and B have ecological deficits, and both are parts of an economic world-system which is characterized by positional competition or in which the actors, knowingly or unknowingly, overshoot their national and global biocapacities. It implies that the stronger nation (A) is not strong enough, and/or the weaker nation (B) not ecologically rich enough, to maintain a unilaterally unsustainable trade.

> "A country that specialises in the production of some raw material, which it exchanges for a manufactured, possibly technically advanced, product, may miss out on the possibilities of learning-by-doing and innovation associated with manufacturing to a larger extent than with the extraction of raw materials or agricultural production […]. Ecologically unequal exchange is the general rule […] In this sense, it is 'natural'" (Anderson and Lindroth 2001:118).

In a 2011 book in which Alf Hornborg (together with Andrew Jorgenson) are editors, Andersson (2011) revises his typology, jettisoning the 'simple' EUE category. But first, he introduces the idea of a "global ethical trilemma" - a conflict between 'prosperity', 'equity', and 'ecological sustainability'. Prosperity is equated with "mass consumption" rather than welfare and, quoting the World Development Report (2006:69), is expected to be attained when "all countries, economically, start resembling countries like the United States (US), thanks to free trade and the diffusion of technology." If this is Andersson's understanding of prosperity, I must object, then we are doomed. As EF analysis tells us, if everybody lived like a resident of the US, based on 2006 figures, we would need five (5) planets, while in 2007 humanity used the equivalent of 1.5 Earths to support its consumption, a 50 percent overshoot (Global Footprint Network 2010). With such a definition of 'prosperity', it is difficult to see how Andersson can expect humanity to achieve ecological sustainability and global justice. No wonder he is convinced that "we can imagine how to achieve two of the goals prosperity, justice, and (ecological) sustainability, but only at the expense of the third" (Andersson 2011:113). It may also explain why he finds the zero-sum perspective of EUE "difficult to reconcile with any view that believes in combining industrial prosperity with either global justice or ecological sustainability" (ibid. p. 122).

Andersson (2011) categorizes "concepts and theories of unequal exchange" into asymmetric, non-equivalent, and disjunctive exchange. The distinction between these categories is, however, not clear. To him, "asymmetric exchange occurs when the *gains* from trade are unequally distributed" (p. 120). We are not told what these "gains" are. Non-equivalent exchange "occurs when there is a discrepancy between a country's exports and imports, *measured in some appropriate standard*" (p. 120, emphasis added). How does this differ from the first, since in both cases there is a *net* transfer or 'gain' of something? Such a standard, we are told, can be "world market prices, emergy, or ecological footprints" (p. 120-121). Here, Andersson does not distinguish between metrics applied in *ecological* (emergy, EF, etc.) and *economic* (money) exchange. In fact, in explaining non-equivalent exchange, he states that "if the prices do not reflect (indirect as well as direct) inputs of labor or biomass, one may say that a country is exploiting another in terms of labor or biomass by means of international trade" (p. 121). But in doing so, he falls into the common confusion that mainstream economists suffer from when they reduce the material (biomass, etc.) to the cultural (money). Monetary prices can never 'reflect' (if by 'reflect' we mean be

equivalent to) biomass or emergy as these are two very different realms - the physical (thermodynamic) and the cultural/symbolic ('value'). As Hornborg (2015:191) puts it, "ecologically unequal exchange cannot be made equal by raising the price of resources, but it can be alleviated or even stopped."[24] Disjunctive exchange, Andersson contends, increases the development gap between the trading countries, and is often asymmetric and non-equivalent, but need not necessarily be so.

Presently, EUE theory is mostly discussed within *ecological economics* and *political ecology*. Ecological economics was founded on an epistemological revolution stimulated by the birth of thermodynamics and has been compared to human ecology because instead of accounting in money, it applies biophysical metrics to economic processes (CEECEC 2009:376-378). Needless to say, biophysical aspects of economic processes are at the core of EUE theory. Costanza et al. (1997) define ecological economics as a transdisciplinary way of looking at the world and whose goals are sustainable scale, efficient allocation, and fair distribution. The influence of mainstream economic theory is thus still evident in ecological economics (e.g. through "efficient allocation"), highlighting the lack of unity and diversity of perspectives even within the discipline. The precursors to modern day ecological economics, according to Hornborg (2011:15-16), were 'academic dissidents' unable to suppress the 'zero-sum game' intuition and, therefore, sought to reveal how the accumulation of money and technology in core areas of the world system occurs at the expense of the natural resources, environment, and health of their peripheries. This suggests that ecological economics, like EUE theory, is not only concerned with the biophysical aspects of economic process, but also fairness and justice issues raised by such processes. Political ecology and environmental justice movements recognize that environmental problems are socially distributed (Hornborg 1998). Martinez-Alier and O'Connor (1996) distinguish between political economy – the study of 'economic distribution conflicts' and political ecology – the study of 'ecological distribution conflicts.' Political ecology takes the view that unequal distribution of the costs and benefits of environmental change inevitably influence socio-economic inequalities and thus have political implications due to a transformation of power relations (cf. Robbins 2004; Blaikie 1985). Ecological economics and political ecology are connected through their mutual concerns with power, poverty, and environmental

[24] Hornborg (2015) goes on to state that "Following the same line of argument, we can conclude that ecological debt cannot be paid, only prevented from increasing" (p. 191). This statement takes a rather narrow view of what 'payment' can mean with regards to ecological debt. Hornborg seems to suggest that because the ecological debt was accrued in 'biophysical' terms, its 'payment' cannot be in monetary terms because money cannot equal matter-energy. This can only be true if he limits himself to a critic of economists' "internalizing of externalities" or the market as a possible means of payment for ecological debt. However, from an environmental justice movement perspective, 'payment' of ecological debt can take many forms, ranging from a simple acknowledgement and recognition of such a debt to redistributive policies such as a basic income grant scheme for people in the Global South (cf. Bond 2010).

transformation using Marxian frames of analysis (Costanza et al. 1997). Martinez-Alier (2002: ix) explains the relation between the two fields of study thus: "...the unavoidable clash between economy and environment (which is studied by ecological economics) gives rise to the 'environmentalism of the poor' (which is studied by political ecology)."

Ecologically unequal exchange raises profound questions about many pertinent issues such as development, equity, justice, and sustainability. It is increasingly recognized as a mechanism underlying the socio-economic and environmental disparities between countries, and is at the core of the development obstacles facing developing countries. It highlights ongoing environmental injustices, and its solution is key to achieving genuine and broad-based sustainable development (Rice 2007). Gauging progress towards sustainability requires a critical and honest analysis of the root causes of the sustainability challenge as well as effective conventional policies with significant impacts in both space and time. EUE theory contradicts many common yet misguided conventional assertions, for example, that the industrialized countries are 'dematerializing' and as such are characterized by the most sustainable environmental policies (Rice 2007). Since the 1992 Rio Earth Summit, it is becoming increasingly clear that conventional environmental management prescriptions, repackaged in mainstream discussions under the banner of "green economy," have serious limitations. The sustainability challenge is symptomatic of deeply rooted fundamental issues incurable by mainstream environmental policy instruments and regulations (Røpke 2001). Similarly, the environmental problems facing the Third World are not simply a reflection of policy or market failure, but rather are a manifestation of broader structural, political and economic forces associated with the worldwide spread of capitalism, and which therefore require far-reaching changes to local, regional and global political-economic processes (Bryant and Bailey 1997). Protection of the environment needs a complete and radical change in the way we structurally organize our socio-economy and unequal power relations, not only between the global North and South, but also internally within regions and countries. If, as EUE theory claims, industrialized countries appropriate a disproportionate share of environmental space and displace significant environmental consequences of their consumption-production-accumulation activities to less developed countries, then the proposition that the developed nations owe some sort of remuneration, an *ecological debt*, to poorer nations is paradigm-shifting. The organization of the contemporary world order is, to a large extent, premised on the assumption that the global North is 'developed'/'rich' and the South is 'developing'/'poor.' EUE theory, especially from an ecological debt lens, overhauls this conception. In this sense, EUE theory is revolutionary. In Paper II, I discuss four potential reasons why it remains underutilized despite its huge potential. These include ongoing elaboration of certain elements of the theory itself, it's very ontology, dominant discourses which

(deliberately?) obscure or misrepresent the theory, and the potential discomfort it portends for those presently benefiting from the EUE phenomenon.

3 Method: Assessing Occurrence of Ecologically Unequal Exchange

3.1 Social Metabolism

Several approaches, methods and metrics to assess the occurrence of ecologically unequal exchange (EUE) exist and more continue to be developed. Such methods quantify the amounts of matter-energy embodied in commodities and therefore exchanged through trade using biophysical measures rather than monetary valuation. In so doing, they provide empirical proof of the occurrence and direction of the asymmetric biophysical exchange. Because such methods quantify, estimate or assess material and energy flows across various socio-economic borders, they are essentially means and tools for evaluating socioecological interaction, societies being subsystems of the biosphere. The flows of matter and energy in such socioecological systems are termed *social metabolism*. Under modern capitalism, trade plays a significant socio-metabolic role.

According to Fischer-Kowalski and Haberl (1997:61), social metabolism is "the mode in which societies organize the exchange of matter and energy with their natural environment," societies being "the *modus vivendi* of the human species" (p. 62). Sometimes called socioeconomic metabolism, social metabolism refers to the material or energy throughput of socioeconomic systems, i.e. all the biophysical resources required for production, consumption, trade, and transportation (Haberl et al. 2013). The concept has been developed as an approach to study the extraction of materials and energy from the environment, their conversion in production and consumption processes, and the resulting outputs to the environment. Derived from its analogy *biological metabolism* in which organisms maintain (or rather, are) a continuous exchange of materials and energy with their environment, providing for their own internal processes of growth and reproduction, socioeconomic systems are similarly constituted by processes of extraction of energy and raw materials from their natural environment, converting them into manufactured or processed products and eventually wastes and emissions through socio-economic production and consumption. Social metabolism is therefore "more or less crude parameters that quantitatively and qualitatively describe the 'input' of a society, the uses this input

serves, and the transformations it undergoes, and, finally, the quantities and qualities of 'output' - that is, off-products of society handed back to nature" (Fischer-Kowalski and Haberl 1997:62). De Molina and Toledo (2014) provide a fairly detailed account of the origins, history, main exponents, interpretations, trends, and literature on the concept of social metabolism.

Modern industrial civilization can be understood as a highly complex socio-natural or natural-social system that requires new paradigms to be better understood. It has become imperative and urgently so to understand the past in order to obtain lessons which can enable us comprehensively understand the contemporary. Such understanding requires comprehensive and interdisciplinary conceptual frameworks capable of orchestrating research into the relations between humans and nature, and making a functional and meaningful analysis of such relations in time and space (de Molina and Toledo 2014). Sustainability science has emerged as a kind of umbrella field within which such efforts are currently organized. Characterized more by its research purpose than by a common set of methods or objects, sustainability science can be categorized into *i)* the more traditional disciplinary-based *science for sustainability* consisting of more descriptive, analytical and basic science, and *ii)* the transdisciplinary *science of sustainability* characterized by reflexivity and applicability (Spangenberg 2011). While I consider sustainability science as encompassing social metabolism and such other interdisciplinary frameworks aimed at understanding socioecological systems, de Molina and Toledo (2014) view sustainability science as still lacking an appropriate theoretical framework that coherently organizes information from various fields and areas of knowledge. To them, the concept of social metabolism is a strong candidate for satisfying that gap.

Sustainability problems can arise at both ends of the societal metabolism (Fisher-Kowalski and Haberl 1997). On the input side is the thermodynamic challenge of resource scarcity. Although (for renewable resources) it can be tackled through what they refer to as *colonization* strategies or what Smith (1990) calls *production of nature*, such efforts also tend to generate sustainability problems of their own. On the output side, sustainability problems arise when the waste materials of societies cannot be usefully or harmlessly absorbed and integrated into the natural environment. Industrial societies which largely rely on inputs extracted not from current renewable biological cycles but from global deposits such as fossil fuels and mineral resources have seen these socio-metabolic problems evolve from local nuisances into global threats. Societal metabolism therefore has two important overlapping aspects - *material* and *energetic* metabolism (Fisher-Kowalski and Haberl 1997):

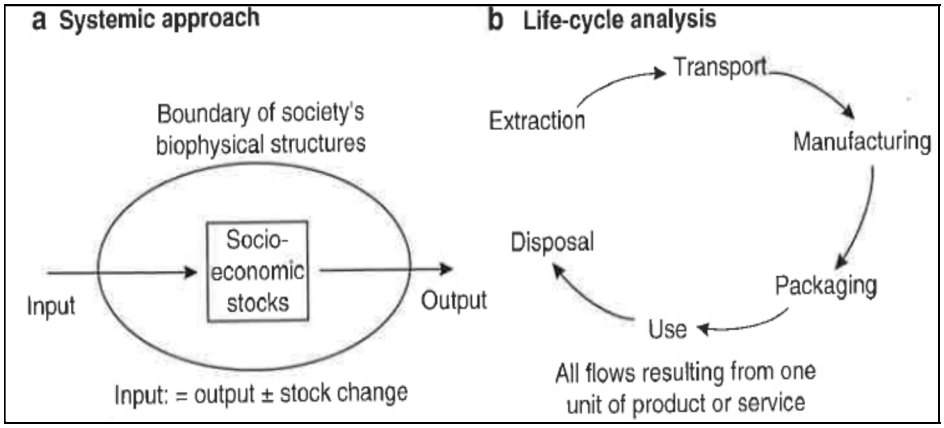
a) **Material flow:** Societal metabolism may be measured in terms of mass input from the natural environment into the socioeconomic system per unit of time (e.g. ton/yr). This mass input is then transformed by the economy and members of that society into some form of output to the natural

environment either within the reference time period (in which case the amount of mass input equals the amount of mass output) or over a longer time period, in which case a certain fraction of the input may be put into stock.

b) **Energy flow:** Just like any other dynamic system of material stocks and flows, socioeconomic systems are driven by an energy flow. The energy supply can come from chemical energy carriers (e.g., biomass, fossil energy, etc.) or solar or geothermal energy, which do not involve direct material input.

3.2 Approaches to Analyzing Social Metabolism

Research on ecologically unequal exchange (EUE) integrates these two aspects of social metabolism as it analyzes the flow of matter-energy embodied in traded goods across socio-economic and political boundaries. In other words, EUE is a global analysis of social metabolism. Haberl et al. (2013) distinguish two approaches to analyzing social metabolism, systemic and LCA approaches. The ***systemic approach*** aims at forging a comprehensive account of all biophysical flows needed to build, sustain, and operate a defined set of socioeconomic stocks for a given reference system identified by scale (global, national, regional) or function (household, economic sector or commercial enterprise). The second approach, ***life-cycle analysis (LCA)***, aims to account for resource requirements as well as wastes and emissions resulting from a single unit of product or service. Because EUE research is analysis of social metabolism, this distinction can be used to categorize the various methods and metrics used to assess the occurrence of EUE. This is what I do in the subsequent sections. The key distinction is thus whether a method takes an aggregate economy-wide approach or focuses on individual products (Fig. 3.1). Some would-be systemic approaches such as carbon footprint analysis are based on LCA, while some such as substance and material flow analysis (SFA and MFA) apply life-cycle thinking (cf. ISO 14040, 2006).



Source: Haberl et al. (2013: 32)

Fig. 3.1:
Approaches to analyzing socieconomic metabolism

In both systemic and LCA approaches to social metabolism, a system boundary needs to be defined and a choice of an appropriate unit of analysis made (Haberl et al. 2013; Fisher-Kowalski and Haberl 1997). Analysis of any material process requires a clear and comprehensive analytical picture of such a process. The picture must first delineate the boundary, an analytical element which separates the process from its "environment," as well as the duration of the process. What the process requires and what it does are then described analytically by the complete time schedule of all inputs and outputs, i.e., the precise moments at which each element involved crosses the boundary from outside or from inside. But where to draw the analytical boundary, the duration to consider, and the qualitative spectrum to use in classifying the elements of the process depend on the intended purpose and existing scientific knowledge (Georgescu-Roegen 1975:350). There is broad methodological consensus on how to establish a theoretically plausible and operationally practical boundary of a socioecological system. One can choose a unit of analysis on several different levels. Globally, such a unit of analysis could be the anthroposphere and its metabolism. In using any unit of analysis below the global one has to take into account that usually there are exchanges with nature and exchanges with other social units. In other words, there are extractions (from nature) and imports (from other social units), and there are emissions (to nature) and exports (to other social units). Extractions and imports can be counted in mass (tons), but one has to be aware that they carry an invisible material load acquired in their (social) system of origin, just as exports leave their material rucksack behind (Fisher-Kowalski and Haberl 1997). Importantly, socioeconomic metabolism applies input-output (I-O) analysis, which is well known to economists.

Some have disputed the logic or even the usefulness of discussing the economy in terms of social metabolism. Dismissing attempts to use ecological concepts in an economic context as misleading and unjustified *eco-eco mismatch*, Ayres (2004) contests the analogies between the economic system and natural ecosystem. Inspired by the differences between thermodynamics and economics discussed in Section 2.2, he identifies four differences between the biosphere (ecology) and the technosphere (economy):

i) There is no primary producer in the economic system analogous to the role that plants play in the biosphere, since inputs to the economy are low-entropy natural resources, capital services, and labor.

ii) In the economic system, output is a heterogeneous mix of manufactured products and services. In the biosphere, there are no products as such, with growth tantamount to accumulation of embodied solar exergy in the form of cellulose, sugars, lipids, and proteins. The biosphere produces only wastes and more of itself plus dead matter.

iii) In the biosphere, there are no markets, no medium of exchange (like money) and there is nothing analogous to paid labor. Exchanges are involuntary, i.e., by predation or parasitism.

iv) Evolution in nature is driven by differentiation, random mutations, and Darwinian natural selection based on reproductive success. In economics, differentiation is based on discovery and innovation by intelligent economic agents and selection is based on competition at the individual or firm level.

Such criticisms of social metabolism and methodologies that are based on them are valid and need to be kept in mind, together with associated problems of social metabolism analysis such as differentiated subsystems (e.g., regions, countries, economic sectors, etc.) and practical calculation and data availability challenges. Nevertheless, we should appreciate that social metabolism and other such 'reductionist' approaches are simply analytical 'models' aimed at understanding, not replacing, complex reality. To some, de-coupling economic growth from underlying biophysical flows is a goal of sustainable development, but a first step toward de-coupling is to develop metrics for quantifying the biophysical flows underlying the economy (Moran et al. 2009). Theoretically speaking, Fisher-Kowalski and Haberl (1997) explain, an analysis of societal metabolism makes sense on many different levels. One of them is in understanding ecologically unequal exchange.

In conventional international monetary trade, exports are good and imports bad since the exporting country receives revenue and foreign exchange while losing the same through imports. The reverse is however true with regards to international trade in physical terms: exports are bad, since the exporting country gives away its material and energy resources, while imports are good, because the importing country receives

the natural resources of the exporting country embodied in the exchanged commodities. This distinction between mainstream monetary economic trade and the alternative view based on biophysical metrics as espoused by ecologically unequal exchange is an important one for the subsequent discussion of EUE measurement methodologies. As Hornborg (2011:2-3) emphasizes, monetary compensation is an ideology of reciprocity underneath which we can discern asymmetric resource flows measurable in terms of embodied hectares, man-hours, joules, liters, or metric tons. Natural resource accounting develops tools that measure the ecological (biophysical) as opposed to financial (monetary) balance of trade (Moran et al. 2009).

3.2.1 Systemic Approaches

Systemic approaches are those that undertake economy-wide material and energy flow analysis. They usually focus on three compartments of society's biophysical structures (Haberl et al. 2013): humans, livestock, and artefacts (infrastructures, machines, buildings, etc.).

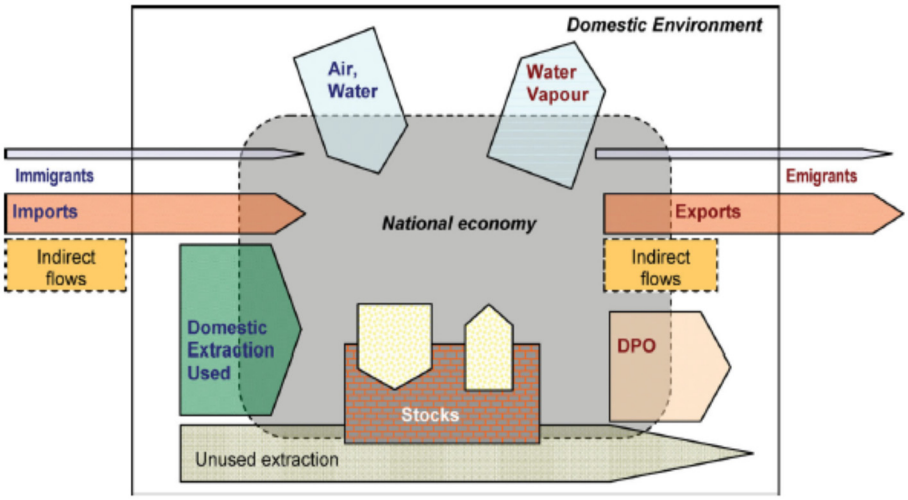
Material Flow Analysis

Material flow analysis (MFA) refers to the analysis of the throughput of process chains comprising extraction or harvest, chemical transformation, manufacturing, consumption, recycling, and disposal of materials. It quantifies the inputs and outputs of a socio-economic system in physical units, usually in metric tons (Bringezu and Moriguchi 2002:79). Robert Ayres (a physicist) and Allen Kneese (an economist) are considered the pioneers, having presented in 1969 the first version of what would, in the 1990s, become MFA (Fischer-Kowalski et al. 2011:857). Their core argument was that the economy draws heavily on common goods such as air and water, a situation which prevents Pareto-optimal allocations in markets.[25] They interpreted such failure of economics as resulting from viewing the production and consumption processes in a manner that is at variance with the law of the conservation of mass, instead proposing that environmental pollution and its control should be viewed as a

[25] Pareto optimality, proposed by Italian sociologist Vilfredo Pareto, argues that economic policies or other social arrangements should not make some people, even if it is only one person, better off while making any other party worse off (Costanza et al. 1997). This Pareto sense of fairness has extensively influenced welfare policies but has been criticized as essentially maintaining the status quo because it implies that the powerful and elite (such as the Global North) should not lose their privileged status in the process of any policy changes. Godelier (1972) argues that "by showing that an optimum could be attained even in a situation where there was inequality in appropriation of the means of production, Pareto introduced …the very form of the fundamental social relation of the capitalist mode of production …one that assumes the fundamental inequality between a class which owns money and means of production and another class which is without these" (p. xvi). Pareto optimality, he adds, involves unequal distribution and, in that sense, its use of the term 'optimum' is a misnomer.

materials balance problem for the entire economy. The law of the conservation of mass is based on the First Law of Thermodynamics and implies that in a closed system (no imports or exports, with no net accumulation of stocks), the mass of the products is always equal to that of the raw materials. The core of MFA is thus the mass balance principle.

Using a 'materials flow' accounting methodology, ecological economists argue that physical numeraries can be used to bring the flows of matter and energy back into the equation (Roberts and Parks 2009:391). The easiest way to do so is by calculating the physical weight of import and export flows. Mass (e.g. tons) is a robust measure which remains unchanged across time and space in classical physics, and can be measured with simple technical means while requiring very little explanation to comprehend (Fischer-Kowalski et al. 2011:856). If time series data for material use is available, it is possible to perform historical analysis on the development of certain environmental pressures for particular countries or the world economy, or incorporate environmental and resource use aspects in evaluations of trade and other economic strategies. Adding the physical dimension of trade delivers information on world resource supply and demand, the scale of resource flows between country groups, and resource dependencies. In general, MFA provides a *system-analytical* view of various interlinked processes and flows (Bringezu and Moriguchi 2002).



Source: Fischer-Kowalski et al. (2011:860)

Fig. 3.2:
Economy-wide material balance model

Material flows can be domestic, come from the rest of the world (RoW), direct, or indirect. Flows or primary materials at the highest level of aggregation are classified into fossil fuels, biomass, industrial minerals and metal ores, and building materials (Fischer-Kowalski *et al.* 2011), and can be disaggregated further and linked to concrete ecological conflicts and remedial measures (Martinez-Alier 2011). Water and air are often represented separately due to their bulk nature. The above MFA model (Fig. 3.1) has several indicators which can be categorized into input, output, consumption, balance, and efficiency indicators (Bringezu and Moriguchi 2002). Physical trade balance (PTB) is an MFA-based balance indicator which measures the physical trade surplus or deficit of an economy or product. PTB expresses whether resource imports exceed resource exports and can help explain the extent to which domestic material consumption is based on domestic resource extraction or imports (Fischer-Kowalski et al. 2011; Bringezu and Moriguchi 2002; Singh and Ramanujam 2011). PTB can therefore give insight into ecologically unequal exchange. Calculations of the PTB of nations generally show that core industrialized countries import much more weight (materials) than they export. Pérez-Rincón (2006) examines Colombia's foreign trade between 1970 and 2002 using MFA. The results show a growing deficit in the Colombian economy's PTB, representing the net export of around 600 million tons, which is the ecological debt that the rest of the world owes to Colombia. Noteworthy is the fact that 85 percent of Colombia's exports are directed at satisfying the material and energy requirements of Northern (core) countries, in particular the USA and the EU. The terms of trade (prices per ton of

exports vs. prices per ton of imports) also show a significant deterioration. Several other studies (e.g. Dittrich and Bringezu 2010; Behrens *et al*. 2007; Bruckner *et al.* 2012; Schaffartzik et al. 2014) apply MFA to arrive at similar proof of EUE.

Bringezu and Moriguchi (2002) distinguish two basic types of material flow-related analysis according to their primary focus (Figure 3.3). Type I analysis suggests that MFA, like LCA, could in principle also be applied to individual products. In practice, however, they explain that whereas type I analyses are often performed from a technical engineering perspective, type II analyses are more directed at socioeconomic relationships. A significant conceptual drawback to the MFA approach is that weighting all trade on the basis of tonnage is not informative regarding the varying ecological impact of the traded goods. MFA provides information about amounts and kinds of physical flows through socioeconomic systems but does not judge whether these flows are justified by the benefits provided or assess the size of unwanted environmental impacts (Fischer-Kowalski et al. 2011:861). For example, Moran et al. (2009:1940) found that one commodity group - mineral products - accounts for approximately 50 percent of the weight of international trade. Yet while mineral products certainly have ecological impacts in their extraction and use, the extent of their environmental impact is likely not directly proportional to their physical weight. One might say that all MFA does is translate economic activity into physical terms, with whatever follows from this requiring additional assumptions. LCA, on the contrary, gives information about the resource intensity and potential environmental impacts of the resource flows. Nevertheless, as a measure of EUE, MFA suggests that core industrialized economies are draining ecological capacity from peripheral regions by importing raw materials and shifting environmental burdens to the South, illustrating how the import of high-quality resources (low entropy) and the export of degraded materials (high entropy) and health risks are two sides of the same coin (cf. Roberts and Parks 2009; Hornborg 2011).

Type of analysis	I		
	a	b	c
Objects of primary interest	Specific environmental problems related to certain impacts per unit flow of:		
	substances e.g. Cd, Cl, Pb, Zn, Hg, N, P, C, CO_2, CFC	materials e.g. wooden products, energy carriers, excavation, biomass, plastics	products e.g. diapers, batteries, cars
	within certain firms, sectors, regions		
	II		
	a	b	c
	Problems of environmental concern related to the throughput of:		
	firms e.g. single plants, medium and large companies	sectors e.g. production sectors, chemical industry, construction	regions e.g. total or main throughput, mass flow balance, total material requirement
	associated with substances, materials, products		

Source: Bringezu and Moriguchi (2002)

Figure 3.3:
Types of material flow-related analysis

Human Appropriation of Net Primary Productivity (HANPP)

Primary production is the process in which green plants produce biomass through photosynthesis, while net primary production (NPP) is the total amount of energy available for ecological food webs and reproduction of biological stocks (Haberl 1997; Haberl *et al.* 2012). Through photosynthesis, plants convert and store the sun's energy, part of which they use for their own functioning and growth. NPP not only provides biomass energy for human existence but also plays an important role for the survival of other species and the functioning of ecosystems. The Human Appropriation of Net Primary Productivity (HANPP) measures how much of the annual biomass accumulation is appropriated by human beings (Moran et al. 2009:1940). It is the sum of changes in NPP resulting from land-use change and human harvest from ecosystems, including losses thereof, and is measured in units of carbon (Haberl 1997; Haberl *et al.* 2012; Martinez-Alier 2011; Krausmann *et al.* 2013). Embodied HANPP (eHANPP) incorporates trade aspects by adding the HANPP related to imported products and subtracting that related to exported products. Krausmann *et al.*'s (2013) analysis of the HANPP trends from 1910 to 2005 for 161 countries aggregated into five regions (Latin America, Asia, Africa, Europe and North America) shows that Asia, Africa, and Latin America experienced double or even triple growth rates in HANPP, while in contrast, it grew only

modestly in the Western industrialized region. They explain this trend by the observed high export of biomass from Latin America and Africa and high consumption of the same by Western industrialized countries.

Footprint Analysis

Footprint analysis has gained prominence in the recent past, and is another tool used to assess ecologically unequal exchange. Footprints represent a partial measure of the extent to which the planet, its regions, or nations are moving along a sustainable development pathway, and have been shown to vary between core and peripheral countries (Hammond 2006). Taking the consumer responsibility approach (Steen-Olsen et al. 2012), they provide a simple, graphic measure of the environmental impact of human activity. Building on the premise that no single indicator is able to comprehensively monitor all human impact on the environment, Galli *et al.* (2012) coined the term 'footprint family' to refer to the three footprints: ecological, carbon, and water footprints. They can be employed at scales ranging from a single product, a process, or a sector to that of individuals, cities, nations, and the whole world.

Conceived in the early nineties by William Rees and Mathis Wackernagel, the Ecological Footprint (EF) calculates human demand on the biosphere and compares it to the planet's ability to meet those demands (Wackernagel and Kitzes 2008). EF measures the amount of biologically productive land area required to produce all the resources an individual, population, or socio-economic activity consumes and requires to absorb the waste it generates, given prevailing technology and resource management practices (Global Footprint Network 2010). It is an integrated measure which builds on the concepts of LCA, bioproductivity accounting, and embodied energy analysis to provide a readily understood numerical indicator (Moran et al. 2009:1939). By estimating how much of the Earth's regenerative capacity is occupied by human activities, EF helps track the use and availability of biological capital over time (Wackernagel and Kitzes 2008). It is measured in global hectares (gha), which is land with world-average biological productivity. When nations consume goods and services the EF of those goods and services may fall outside their borders, in which case they can be said to be 'importing' biocapacity or productive land area. Conversely, countries exporting goods and services produced using domestic ecological resources are exporters of Ecological Footprint. In this way, the unequal exchange of EF can be assessed. In addition, countries also use resources of the global commons, e.g. oceans and atmosphere, as sinks for greenhouse gases (GHGs). In some respects, EF has similarities with MFA, HANPP, and even eMergy (Moran et al. 2009).

The water footprint (WF) or 'virtual water' is the total volume of freshwater used to produce a good or consumed by a community (cf. Hoekstra 2009; Hoekstra et al. 2009; Mekonnen and Hoekstra 2011; Hoekstra and Chapagain 2007). Expressed in volume per unit of product (m^3/t), the WF is a combination of the blue, green and

gray water footprints. The green water footprint is the volume of rainwater consumed, while the blue water footprint is the volume of surface and groundwater used. The grey water footprint, on the other hand, is the volume of freshwater that is required to assimilate the load of pollutants based on ambient or existing water quality standards. The water footprint of a crop (m^3/ton) is calculated as the ratio of the volume of water (m^3/ha) consumed or polluted during the entire period of crop growth to the corresponding crop yield (ton/ha). The grey component of the water footprint of crops (m^3/ton) is calculated by dividing the amount of nitrogen that leaches to the water system (kg/ha) by the maximum acceptable concentration of nitrogen (kg/m^3) and the crop yield (ton/ha). Hoekstra (2009) has compared the ecological and water footprints. They are not yet full measures of sustainability, as several environmental, economic and social issues are not tracked (Galli et al. 2012). Nevertheless, they are able to complement traditional analyses of human demand by coupling producer and consumer perspectives, while presenting a quantifiable and rational basis on which to assess, among other things, ecologically unequal exchange.

The carbon footprint is the total amount of carbon (or CO_2 equivalent) emissions caused by or accumulated over the life of a product or activity, or the sum of a country's emissions related to its consumption, including imports but subtracting exports (Galli et al. 2012). It is expressed in tons of CO_2 with no conversion to area. Primarily a measure of the appropriation of global sink capacity, the carbon footprint can also gauge EUE. Steinberger et al. (2012) have shown that socio-economic benefits are accruing to carbon-importing rather than carbon-exporting countries. While PTB measures resource extractions, the balance of embedded CO_2 emissions in trade (BEET) measures environmental load displacement. Just as countries with a balance-of-trade surplus export more than they import, countries run a surplus on the BEET where the emissions involved in producing the goods they consume (including those produced abroad) are less than the emissions from domestic production (Pan et al. 2008). The flow of carbon is studied because it is linked to global warming and the hypothesis being tested is whether pollution and CO_2 intensive manufacturing moves from developed to less developed nations (Moran et al 2009). Whether a country has a BEET in deficit or surplus depends on whether the goods it consumes embody more or less emissions than the goods it produces. Current Kyoto Protocol accounting procedures are production-based rather than consumption-based. Steen-Olsen et al. (2012) have shown that the EU-27 displaces all the three environmental footprints to the rest of the world through trade.

Input-Output Analysis

At a very elementary level, input-output analyses are embedded in all the approaches to analysing social metabolism. However, input-output (I-O) analysis is also a specialized method of systematically quantifying the mutual interrelationships among the various sectors of an economic system, which can range from a single household

or city to a country or the entire world economy (Leontief 1986). Introduced by Wassily Leontief in the 1930s, input-output (I-O) analysis describes and explains the level of output of each sector of a given economy in terms of its relationships to the corresponding levels of activities in all the other sectors (Leontief 1970). If extended to diverse multi-regions, the I-O approach enables explanation of the spatial distribution of output and consumption of various goods and services and of their growth or decline over time. This way, any unequal exchange between different economies can be compared. Initially applied mainly to economic impact analyses in monetary units through monetary input–output tables (MIOTs), they have since been extended to incorporate pollution and other environmental "externalities" (Leontief 1970; Allan et al. 2007). Environmental I-O approaches can extend MIOTs by environmental data in either monetary or physical units, in hybrid models, or by expressing all economic transactions in physical terms through physical I–O tables (PIOTs) (Giljum and Hubacek 2004). A PIOT is a macroeconomic activity-based physical accounting system comprising not only the product flow of the traditional I-O table in physical units, but also material flows between the natural environment and the economy (Strassert 2002). An I–O approach has the advantage of tracking the transformation of goods through the economy, tracing impacts from final products back to raw resources as well as capturing the impact of exchanged services (Moran et al. 2009). Conventional I-O tables also often include labor in man-years under the "value-added" row (Leontief 1970). Comparing the treatment of unequal exchange among Marxists and ecological economists, Lonergan (1988) notes that one method appropriate to the measurement of unequal exchange, *input-output analysis*, is applied consistently by both groups. However, poor data availability and low product resolution are some of its weaknesses, coupled with the fact that few non-OECD nations publish trade statistics in I–O table formats (Moran et al. 2009).

Energy Metrics

Energy accounting and the application of appropriate energy metrics such as eMergy (energy memory), exergy (the amount of available or useful energy put to work), primary energy input, energy return on investment (EROI), and total primary energy supply (TPES) are other parameters which can potentially be used to assess ecologically unequal exchange. In his book *Environmental Accounting: Emergy and Environmental Decision Making*, Howard T. Odum (1996:1) claims that eMergy, the energy already used directly or indirectly to create a service or product, offers a science-based evaluation system that represents both the environmental and the economic values using a common measure. The divergence between economics and thermodynamics on the issue of 'value' is discussed in Section 2.2, and Paper II. Also denoted *embodied energy*, eMergy can be thought of as "energy memory" since it is calculated by adding up all the energies at different levels that combine to produce the product or service (Odum 1997:88). Such energy flow-based parameters can be used to measure unequal exchange (Bringezu and Moriguchi 2002:85). Alfred Lotka

(1922a, 1922b, 1925) postulated that natural selection favors those populations that convert the greater amount of energy, a principle later reformulated and renamed the "maximum em-power principle" by H.T. Odum (cf. Odum 1995; Sciuba 2011). The implication of Lotka's *maximum power principle* for interregional trade is that regions that import more embodied energy than they export will have a relative economic advantage (Lonergan 1988). As a result, Lonergan explains, attempts have been made to extend the maximum power principle to international trade by suggesting that social systems may exploit the energy resources of others in order to survive and dominate. This has been demonstrated by Odum (Odum and Arding 1991; Odum 1996). Rydberg (2011), building on Odum, uses eMergy to assess unequal exchange, concluding that developed countries mostly base their development on a large share of imported eMergy, since trade with peripheral countries confer a net eMergy advantage to the former, a process often erroneously referred to as higher "trade power."

3.2.2 Life Cycle Analysis (LCA)

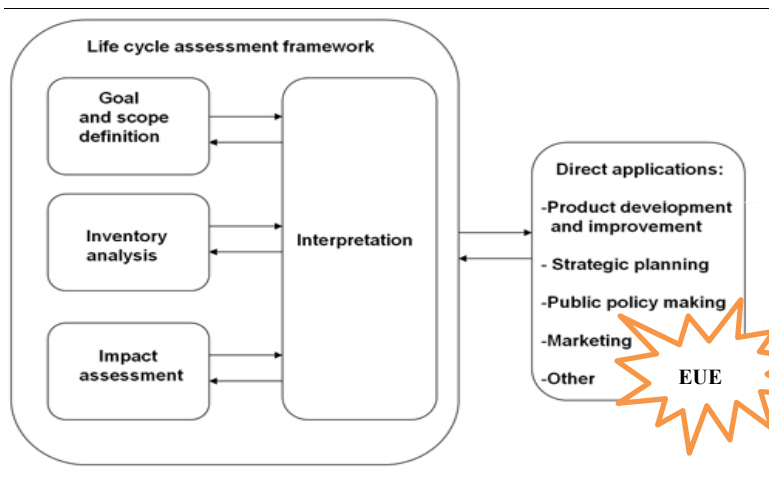
LCA is a compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a *product system* throughout its life cycle (ISO 14040, 2006). It addresses the resource intensity and potential environmental impacts throughout a product's life cycle. Compared to other methods of environmental assessment, the most important characteristics of LCA is that it assesses the environmental performance of a product from resource extraction to end-of-life treatment and 'translates' the inputs and outputs into potential environmental impacts (Thrane and Schmidt 2007). By considering the entire life cycle of a product, the so-called cradle-to-grave approach, it means that the material and energy throughput and environmental consequences of the entire production process from raw material extraction, transportation, processing, distribution, use, end-of-life treatment, recycling, and final disposal are considered (ISO 14040, 2006). Through such a systematic overview and perspective, the shifting of environmental burdens between different production stages or individual processes can be identified and possibly avoided. LCA can be used to identify "hot spots" - opportunities for environmental improvement in a product's life cycle, for decision-support, selection of environmental performance indicators, and marketing (e.g. in eco-labels and environmental declarations/claims). That is why LCA is a favourite tool in environmental improvement and sustainable production and consumption policies. Curran (1997) examines how different LCA approaches are being applied internationally in the development of various government policies.

The roots of LCA go back to the late 1960s and early 1970s when environmental studies applying the life cycle perspective were used to estimate the environmental

burden for beverage containers and the energy used to produce different packaging materials. Having gained momentum in the late 1980s, the first LCA guidelines (termed the 'Code of Practice') were developed and published in 1993 by the Society of Environmental Toxicology and Chemistry – SETAC (Thrane and Schmidt 2007). The Code of Practice has been replaced by the much more detailed ISO Standards. Because there are many potential ways of conducting an LCA study, the International Standards Organization (ISO) has developed guidelines on how to conduct LCA as a way of harmonizing the production process and products across different industries and countries to ensure quality, safety, and efficiency and, more importantly, to facilitate international trade. These are ISO 14040, 2006 (LCA – Principles and Framework) and ISO 14044, 2006 (LCA – Requirements and Guidelines). These guiding principles and framework were used in Paper I and are the basis of the following overview. The ISO is a membership organization made up of 163 member countries around the world (ISO 2015). With its secretariat in Geneva, Switzerland, the ISO is the world's largest developer of voluntary international standards. SETAC is still active in improving LCA guidelines and has, together with UNEP, developed the Social and Economic LCA guidelines (UNEP 2009).

The LCA Process

An LCA study is made up of four phases, namely goal and scope definition, inventory analysis, impact assessment, and interpretation (ISO 14040, 2006). The relationship between the four phases is illustrated in Fig. 3.4 To this framework, as part of the category 'other' under 'Direct applications,' EUE can now be added based on Paper I.



Source: Adapted from ISO 14040 (2006:8)

Figure 3.4:
Phases of an LCA study

Phase 1: Goal & Scope

The goal of a LCA expresses the reasons for conducting the study, intended application, and the target audience or end users. The scope of the study, which should be sufficiently broad, deep, and detailed to address the stated goal, is described in terms of the *functional unit*, *system boundary*, the *product system* and relevant processes, *impact categories*, *allocation procedures*, and data requirements (ISO 14040, 2006). The functional unit defines the quantified functions or performance characteristics of the product. Its primary purpose is to provide a reference to which the inputs and outputs are related to ensure comparability of LCA results, especially when different products or production systems are being assessed. The functional unit may reflect a quantity (amount, volume, or size), a duration/period, and/or qualitative characteristics (Thrane and Schmidt 2007). The conduct of LCA, like socio-metabolic studies, is based on analytically defining the product systems of interest. The system boundary thus defines the unit processes to be included in the system. The system boundary is dependent on the goal and scope, intended application and audience, data availability and costs involved, as well as cut-off criteria (what and why certain aspects are left out). It is important to note that LCA is an iterative process (indicated by the double arrows in Figure 3.4) in which various aspects of the scope may require modification as more data and information become available, or as the researcher conducting the study becomes more focused in order to meet the original goal of the study.

Different levels of ambition can be chosen when conducting a LCA (Thrane and Schmidt 2007). The simplest approach is a *conceptual LCA*, a qualitative assessment of the environmental aspects from cradle to grave which, besides basic environmental knowledge, does not require knowledge of LCA methodology. A *screening LCA* requires quantitative data and knowledge of LCA methodology. It is also possible to limit the data collection, for instance only to energy consumption, while the impact assessment may be limited to addressing only a few impact categories such as global warming. The *detailed LCA* includes a comprehensive data collection, a high level of data quality, and a larger number of impact categories. However, it is often difficult in practice to clearly distinguish between a screening and detailed LCA. The LCA technique can also be applied to studies that only address parts of the life cycle, e.g. the first stages in the life cycle from raw material acquisition to processing (cradle-to-gate), a single life cycle stage such as processing (gate-to-gate), or studies which only address, for example, waste management systems or specific components of a product. The ISO 14040, 2006 recommends that such studies are not referred to as LCAs but rather as studies that apply the LCA technique.

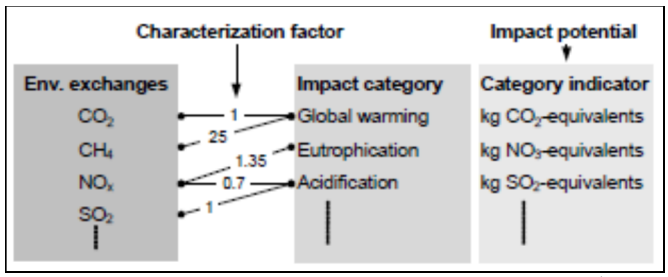
Phase 2: Life Cycle Inventory (LCI)

The Inventory phase involves data collection and quantification of relevant inputs and outputs of the product system (ISO 14004, 2006). Data collection is done for

each unit process and includes energy inputs, raw materials, ancillary and other physical inputs, products, co-products and waste, and emissions and discharges to air, water and soil. The data must then be related to the functional unit defined in the goal and scope definition. Data can be presented in tables and some initial interpretations can be done (Thrane and Schmidt 2007). The LCI thus provides information about all inputs and outputs in the form of elementary flows from all the unit processes within the system boundary. Elementary flows are matter-energy flows from or to the environment without any previous or further human transformation.

Phase 3: Life Cycle Impact Assessment (LCIA)

This phase is aimed at evaluating the significance of potential environmental impacts using the LCI results. In other words, this step evaluates the contribution of the inventory results to the various impact categories chosen at the goal and scope definition phase. It involves associating inventory data with specific environmental impact categories and category indicators as a way of understanding these impacts (ISO 14040, 2006). This is an advantage that LCA has over systemic approaches such as MFA which do not tell us the environmental impacts of the resource flows. Impact categories can be grouped into environmental or resource consumption impacts and can have local, regional, or global effects (see Figure 3.6). Some elements of LCIA are mandatory (selection of impact categories, classification, and characterization) and others optional (e.g. valuation). Classification involves assignment of LCI results to impact categories, while characterization is the conversion of LCI results to common units and their aggregation within the impact category (Thrane and Schmidt 2007). The characterization results show how much various processes, life cycle stages, or entire product systems contribute to different impact categories (see Figure 3.5).



Source: Thrane and Schmidt (2007:230)

Figure 3.5:
Characterization process

Valuation involves normalization and weighting, i.e. the application of normative judgements, and is optional according to ISO 14040 (2006) due to lack of international consensus. It is important to note that under LCIA, only *potential*

impacts are considered. Whether the potential impacts eventually materialize depends on many other factors such as precise fate, exposure, background concentrations, recipient sensitivity, and so on (Thrane and Schmidt 2007). In this respect, LCA can be perceived as an inherent precautionary principle, taking a strong sustainability stance, since all potential impacts are assumed to materialize.

	Environmental impact	Resources consumption	Other related impacts
Globa	• Global warming (GWP) • Ozone depletion (ODP)	• Depletion of non-renewable resources	
Regional	• Photoch. ozone formation • Acidification • Nutrient enrichment • Ecological toxicity • Human toxicity	• Depletion of renewable resources at regional scale	• Radiation
Local	• Ecological toxicity (acute) • Human toxicity (acute) • Waste • Damage to the seabed • Land use	• As above but local scale	• Occupational H&S • Animal welfare • Noise • Odour • Accidents • Aesthetics • Radiation

Source: Thrane and Schmidt (2007:221)

Figure 3.6:
Potential environmental impact categories

Phase 4: Interpretation

The findings from the inventory analysis (LCI) and impact assessment (LCIA) are considered together in a bid to deliver results which are consistent with the defined goal and scope, and to reach conclusions, explain limitations, and provide recommendations (ISO 14040, 2006). The objective of this phase is to structure and present the key results in accordance with the LCA study's goal and scope (Thrane and Schmidt 2007). If the purpose was to establish 'hot-spots' – production stages with largest environmental impact potentials - a contribution analysis should be done. A management influence analysis can also be done if the goal and scope is to determine possibilities for action. It is also possible to differentiate between different groups of processes such as transport, energy, or cooling (dominance analysis). Besides presenting the most important results, the interpretation phase also includes a critical reflection about the study, uncertainty, sensitivity, and methodological choices.

LCA has clearly emerged as the favorite tool in evaluating or comparing the resource consumption and/or environmental impacts of different products and production systems. However, like any tool, LCA has its limitations (ISO 14040, 2006). It only addresses the environmental aspects and impacts of a product system. This means that economic and social impacts are typically outside its scope even though other tools can be combined with LCA for more extensive assessments. To address this gap, social and economic LCA guidelines have been developed to complement

environmental LCA (see UNEP 2009). LCA is structured around the concept of a *functional unit*. However, it is difficult to compare the environmental or eco-profiles of products or product systems with completely different characteristics (Ayres 1995). In many cases, LCA only expose the tradeoffs and can rarely point unambiguously at the 'best' technological choice. LCA studies may produce results with significant uncertainty and based on embedded political choices, especially during system delimitation, normalization and weighting (Thrane and Schmidt 2007). Furthermore, there are a number of 'hidden' assumptions that represent a kind of concealed weighting, e.g. the equal treatment of future and current environmental impacts. In a nutshell, LCA does not apply any discounting in contrast to economic methods such as cost-benefit analysis (CBA), which means that the future (and future generations) are considered as important as the present, while impacts on humans are considered equal across the globe without taking into consideration socio-economic conditions, power relations, and/or historical and structural differences. LCA is also data intensive and the data is normally not available from published sources but rather are retrieved from 'confidential' or private sources which are often unverifiable and may well be erroneous. For example, in the Kenyan case studies (Paper I), I relied on some data from the records kept by the target flower and coffee farms. Triangulation with other data sources can remedy this. Ayres (1995) adds that another challenge is that theoretical process descriptions from literature may not correspond to actual practice. Despite these drawbacks, LCA has utility as an EUE assessment methodology.

An LCA-Based Methodology and Case Study

The above review of systemic approaches to analyzing social metabolism reveals that some of them can in principle be applied to individual products as well as entire economic systems. This in a sense contradicts Haberl et al.'s (2013) distinction of systemic and LCA approaches on the basis of their focus on entire economic system versus individual products, respectively. But as Haberl and colleagues admit, the distinction is at a very basic level. They note that LCA is mainly used to optimize production chains and posit that, although LCA might in the future become relevant to the study of socioecological systems across space and time (i.e. social metabolism), to their knowledge it has so far not been used in this way. The introduction and testing of an LCA-based methodology for estimating EUE in Paper I is partly a methodological response to this knowledge gap.

Each of the approaches reviewed, like any model, has its strengths and weaknesses. In developing and empirically testing my own methodology for estimating EUE, I chose LCA and not the other so-called systemic approaches for the following reasons:

i) While in principle it is possible to apply the systemic approaches to individual products, in practice, empirical EUE studies have adopted aggregated economy-wide national or regional approaches.

ii) The aggregated economy-wide approach adopted by many empirical EUE studies, I contend, has partly contributed to the underutilization of the EUE theory (I discuss the utilization of EUE in Paper II). In my view, though necessary in broadly demonstrating the occurrence of EUE, such aggregated studies make EUE appear overly abstract. Focusing on individual products and countries, as I do, can make EUE appear more concrete and thus easier for local communities, decision-makers, and environmental justice movements to relate to, translate, adapt, and work with in their everyday work.

iii) LCA is a much more widely used tool compared to those commonly used in empirical EUE studies. It is the tool of choice for many sustainable consumption and production policies (SCP) and, unlike the systemic approaches; it has been internationally agreed upon and translated into international standards (ISO 14040 and 14044). One can argue, therefore, that much more scientific research and political interrogation has gone into the theoretical and conceptual development of LCA than into the others.

Based on the above LCA framework, I develop a methodology for assessing the occurrence of EUE. The methodology is then tested in the exchange of Kenyan rose flowers and coffee and Dutch cheese. These analyses are explained in detail in Paper I. The proposed methodology can be summarized as having two key parts. The first involves determination of the resource intensity per functional unit (kg) using LCA. The second is the determination of resource intensity per unit of exchange value (US dollar) based on prevailing international exchange rates. The resource intensities per dollar are then compared to determine the net (unequal) exchange and direction of resource flows and environmental impacts over several years.

4 Policy: International Trade and Justice

4.1 Public Policy and Sustainability

Policy-making, according to Hajer (1995) "is not just a matter of finding acceptable solutions for preconceived problems. It is also the dominant way in which modern societies regulate latent social conflicts" (p. 2). Hajer raises two issues that are important to understanding contemporary environmental problems and the potential policy response to them. First, problems are 'preconceived', i.e. issues or 'problems' become so based on their specific conception, definition, or construction by particular groups in society. This, he emphasizes, is not to mean that there are no environmental challenges 'out there' but rather that reality "is always particular, it is always dependent on subject-specific framing or time-and-place specific discourses that guide our perceptions of what is the case" (ibid. p. 17). Second, (environmental) policy is essentially a process of conflict resolution. That is, environmental problems are a manifestation of latent *social* conflicts which may be cultural, economic, or political, a pointer to the antagonistic nature of social relations. These two points, Hajer believes, suggest that environmental crises have become discursive, a matter of interpretation. Whose 'interpretation' or discourse 'wins' to eventually become hegemonic is dependent on many factors, among them, existing power relations, strategic use of knowledge or 'science', particular tactics employed, and the socio-political institutions roped in to further a particular discourse.

The publication of *Our Common Future* (WCED 1987), commonly known as the Brundtland Report, (re)introduced and created a seeming global consensus around the concept and need for sustainable development. Sustainable development questions the post-1945 claim which still dominates much mainstream economic policy that increased global trade and industrial growth is the best way to achieve international prosperity and human well-being by recognizing that past growth models not only failed to eradicate poverty, such patterns of growth has also damaged the environment upon which livelihoods depend (Hopwood et al. 2005). Sustainable development is commonly understood as development that meets the needs of the present without compromising the ability of future generations to meet their own

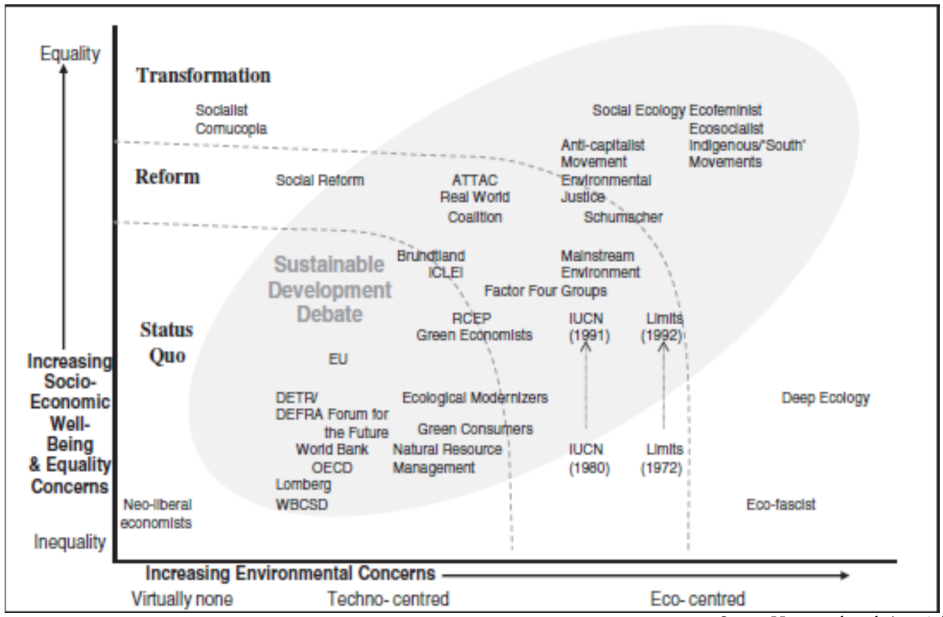
needs. It entails: i) the concept of 'needs,' i.e. that the essential needs of the world's poor should be given "overriding priority" and, ii) that there are limitations imposed by technology and social organization on the Earth's ability to meet present and future human needs (WCED 1987). The sustainable development concept thus has at its core the need to meet the essential needs of the world's poor, and that this is a global priority. Any interpretations of sustainable development or sustainability which do not recognize and incorporate this essential element are therefore misplaced. The second aspect of sustainable development draws attention to the limits of technology and social organization in 'remaking' the Earth in an attempt to satisfy human needs. This puts a caveat on the apparent limitlessness of possibilities offered by technological innovation and economic growth that guide the ecological modernization discourse (see Section 4.2 below). However, it does not in itself acknowledge the physical limits that the Laws of Thermodynamics put on the Earth's resources and which therefore also put limits on endless economic growth (cf. Dobson 1996; Hopwood et al. 2005).

While recognizing that interpretations will vary, the Brundtland Report was categorical that socio-economic goals of development must be defined in terms of sustainability in all countries, and that "sustainability cannot be secured unless development policies pay attention to such considerations as changes in access to resources and in the distribution of costs and benefits" (WCED 1987: Chapter 2, p.1), a reference to social equity within and between generations. In a direct reference to the nexus between power and environmental degradation, the report states that "many problems of resource depletion and environmental stress arise from disparities in economic and political power" (ibid. Chapter 2, p.4). Social equity and justice, therefore, are crucial parts of the sustainable development debate, and should constitute key pillars of any public policy at national, regional, or international levels.

As one would expect, since the publication of the Brundtland Report, hundreds of working definitions of sustainable development have been reported (cf. Hajer 1995; Dobson 1996), an indication of the ongoing re-interpretation and possible re-negotiation of the sustainable development concept. Sustainable development is thus a contested concept with divergent environmental and socio-economic outlooks (cf. Hopwood et al. 2005). According to Martinez-Alier (2002), the global environmental movement worldwide is divided into three: the dominant 'cult of wilderness,' the 'gospel of eco-efficiency,' and a growing third current called 'environmentalism of the poor.' Such contestation has seen a split into 'weak' and 'strong' sustainability, definitions which have a foundation in economics and which are based on different philosophical and ethical dimensions (c.f. Beckerman 1995; Daly 1995; Dobson 1996; Neumayer 2003; Hopwood et al. 2005; Davis 2013). According to this distinction, 'weak sustainability' assumes that man-made/human capital can (nearly perfectly) substitute for, or is interchangeable with, natural capital, with technology able to fill any human-produced gaps such as resource scarcity or environmental

damage. On the other hand, 'strong sustainability,' which is influenced by 'deep ecology,' criticizes this position by arguing that natural capital is not substitutable or replaceable by human capital. In this 'weak' vs. 'strong' sustainability debate, 'capital' (natural or human) is the important thing 'being sustained' or passed on across generations such that under strong sustainability, the next generation is bequeathed the same amount of natural capital while human capital increases over time, but under weak sustainability, the next generation receives a lower level of natural capital but higher human capital (cf. Davis 2013; Dasgupta 2007). Engaging with such 'weak'/'strong' sustainability debate requires one to accept the distinction within economics between 'natural' and 'human' capital, a distinction which can mislead since, from a thermodynamics perspective, production does not change matter-energy (First Law of Thermodynamics) even though disorder is increased as natural resources are dissipated through the process of economic production (Second Law of Thermodynamics). However, from an EUE perspective, the distinction becomes important since the accumulation of 'industrial technomass' (so-called 'human capital') in parts of the world is symptomatic of unequal exchange, what Hornborg (2011, 2001) has termed *machine fetishism*.

The strong versus weak sustainability debate has been criticized as being conducted mainly around environmental issues and future generations without consideration of the socio-economic consequences for and within current generations (Hopwood et al. 2005). Ironically, therefore, it misses what is a key point of the whole sustainability debate – social equity. No wonder, based on the 'weak'/'strong' sustainability distinction, that Davis (2013:114) has the audacity to state that "at present, the trajectory of the developed world is arguably tending towards the stronger end of the spectrum" …while "the developing world […] damages natural capital" hence are at the weak end of the sustainability continuum. This is in direct contrast to EUE theory. The apparent 'sustainability' or 'dematerialization' occurring in the Global North is at the expense of resources extracted from the Global South and a prodigious use of the Earth's sink capacity, while the apparent damage to the natural world by the Global South is due to the accelerated export of resources (e.g. HANPP) to feed industrial processes in the North (cf. Krausmann et al. 2013). International trade and growth, therefore, is benefiting the core industrialized countries but not the periphery. This is one of the criticisms directed against the mainstream economics position on trade – assuming too easily a positive relationship between international trade and economic growth (Muradian and Martinez-Alier 2001).



Source: Hopwood et al. (2005:41)

Figure 4.1:
Views on sustainable development

The concepts of environmental Kuznets curve (EKC) and 'environmentalism of the poor' highlight how sustainability is viewed differently in the core (North) and periphery (South). The belief that there is a positive relationship between economic growth and environmental quality is supported by the EKC in which (environmental) economists assume that economic growth and higher incomes will change preferences towards the environment, i.e. environmental damage increase at first but starts to decrease as a country becomes rich and per-capita incomes rise, an inverted U-shaped curve (Muradian and Martinez-Alier 2001; Anderson and Lindroth 2001). The EKC is thus a hypothesized relationship between various indicators of environmental quality and per-capita incomes such that in the early stages of economic growth, degradation and pollution increase but beyond some level of incomes, the trend reverses such that at high income levels, economic growth leads to environmental improvement. The critique of the EKC has been mounted from theoretical, methodological, and empirical fronts. According to Stern (2004:1421), "EKC has never been shown to apply to all pollutants or environmental impacts and recent evidence…challenges the notion of the EKC in general." The EKC has been used to advance two erroneous assumptions:

i) That general economic growth is good because as GDP and per-capita incomes rise, the level of environmental quality will also rise. This sustains the growth mantra/imperative even in the developed North where it does not bring about any significant increase in welfare while increasing resource throughput. The increased resource consumption, as I discuss in Paper II, is due to the iteration of the treadmill logic of capitalism and natural resource extraction which is one of the key processes through which EUE occurs.

ii) That developed industrialized countries are 'green' or environmentally sustainable because they have attained high per-capita incomes. By implication, therefore, developing peripheral countries which still have high poverty levels and low per-capita incomes are environmentally unsustainable. This claim is oblivious to the fact that no actual 'dematerialization' is happening due to the scale effect, the Jevons paradox, and the importation of sustainability through biophysical unequal exchange.

The EKC is a classic example of how the science of (environmental) economics is used to support and advance neoliberal and ecomodernist discourses which not only disregard the existence of EUE phenomena, but twist reality to suit particular interpretations and interests. Martinez-Alier's (2002) "environmentalism of the poor" takes a contrarian position, arguing that economic growth means increased environmental impacts and emphasizes *geographical displacement* of sources and sinks, a position shared by EUE theory, thus challenging many of the neoliberal end ecomodernist positions. Variously called popular environmentalism, livelihood ecology, liberation ecology, or even the environmental justice movement, environmentalism of the poor argues that "the industrial countries are dependent on imports from the south for a growing part of their growing requirements of raw materials or consumption goods" (ibid. p. 10) and that "this creates impacts which, before there is time to redress them through economic policy or changes in technology, have already been felt disproportionately by some social groups that often complain and resist" (ibid. p. 11). The thesis of the ''environmentalism of the poor,'' Martinez-Alier (2014) emphasizes, is not that as a rule the poor are 'naturally' or transcendentally environmentalists. Rather, in many historical and contemporary cases of resource extraction and waste disposal conflicts, they are often on the side of the conservation and preservation of nature against corporate interests and state policies, a behavior that is consistent with their interests which are most directly dependent on the environment. This is because while wealthier people in the North have in general lost touch with the fact that the environment is their source of livelihood, since they consume large amounts of imported resources and produce increasing amounts of waste which they export elsewhere à la Lawrence Summers' principle (see Box 4.1), the poor and largely rural populations of the South are more directly connected to and therefore have a more intimate understanding of – and higher stakes in – the conservation of the environment. As Georgescu-Roegen

(1971:277) notes, "of all necessaries for life only purely biological ones are absolutely indispensable for survival. The poor have had no reason to forget it." Environmentalism of the poor is therefore not so much concerned with revering nature for its own sake or defending the rights of other species and future human generations. Its ethics derive from a material interest in the environment as a source and a requirement for livelihood, a concern for today's poor, and a demand for contemporary social justice among human beings (Martinez-Alier 2002). At its core are concerns for social justice, recognition and participation in decision-making, and a strong belief that human rights, environmental protection, and self-determination go hand in hand (Martinez-Alier 2014).

While the ongoing renegotiation of the concept of sustainable development is commendable and was in fact anticipated by the Brundtland Report itself, we must interrogate the assumptions and motivations behind and merits of such efforts. Hajer's (1995) contention that ecological crises are a matter of interpretation or discourse, and the Brundtland Report's caution that many environmental problems are the result of unequal economic and political power relations, are among perspectives which guide EUE theory to question the unequal power and ability to organize the world-economy that core industrialized countries wield over the physical and social environments of the global South. Georgescu-Roegen (1971:306) is optimistic that feeding the world's over seven billion humans is possible but cautions that to do so "demands that the town should abdicate its traditional economic privileges." The town he is referring to is, from a world-system and EUE perspective, the industrialized North. Contemporary policies are therefore assumptions or implicit theories which must be thoroughly tested against a plurality of genuine 'values' or viewpoints, many of which are incommensurable. A socially just way of addressing such incommensurable values and conflicts is thus the hallmark of a sustainable policy and society.

4.2 Ecological Modernization

In 2015, a group of eighteen "scholars, scientists, campaigners, and citizens" published what they called *An Ecomodernist Manifesto* (see Asafu-Adjaye et al. 2015). One would think that ecological modernization (contemporary conventional environmental policy) is already too entrenched to require a manifesto. Nevertheless, the Ecomodernist Manifesto (hereafter EM) believes it needs "to affirm and to clarify our views and to describe our vision for putting humankind's extraordinary powers in the service of creating a good Anthropocene" (ibid. p. 7). They even have a version of it in my native Swahili language. Many have criticized the EM from various perspectives (cf. Caradonna et al. 2015; Monbiot 2015). Technology and more

economic growth are to ecomodernists the solution to the problems of a 'bad Anthropocene'. The EM authors note that "human flourishing has taken a serious toll on natural, nonhuman environments and wildlife" (p. 9) but emphasize that humans are not doing more harm to themselves! How they can fail to appreciate that humans are harming other humans through degradation of the environment given the current levels of global inequality and the zero-sum understanding of EUE is unfathomable. Hajer (1995:24-41) criticizes ecological modernization as, among other things, i) suggesting a positive-sum solution to a zero-sum problem, ii) explicitly avoiding to address basic social contradictions by not calling for any structural change, and iii) presenting itself as a strategy to politically accommodate the radical environmental critique of the 1970s, which brought together environmental conservation and self-determination.

The brief biographies of the authors of the EM give a glimpse of what is at the core of ecological modernization. Linus Blomqvist's research, we are told, "focuses on how *technological progress* is *decoupling* humanity's environmental footprint from economic growth" (EM p.3). The authors themselves believe that "decoupling of human welfare from environmental impacts will require a sustained commitment to technological progress and the continuing evolution of social, economic, and political institutions alongside those changes" (p. 29). In fact, the authors do not believe that physical limits on Earth's biocapacity should put any limits on human population and economic expansion. To them, "to the degree to which there are fixed physical boundaries to human consumption," they [notions of physical "limits to growth"] are so theoretical as to be functionally irrelevant (Asafu-Adjaye et al. 2015:10). However, under capitalism, with its growth imperative, it is impossible to decouple environmental degradation from economic growth, considering the discrepancy between economics and thermodynamics (see Section 2.2). This justifies Hajer's (1995) criticism that ecomodernists do not call for any structural change. Decoupling is often thought of in terms of 'dematerialization,' an apparent reduction in absolute throughput in the industrialized core countries. But from an EUE perspective, which is supported by many empirical studies on resource flows, the dematerialization is simply an 'importation of sustainability' which overall increases the use of resources embodied in imports but makes the consumption of *local* resources appear to decline. Most of the EM authors share the belief that economic growth is necessary and that technology will solve any negative environmental and social impacts ('externalities') caused by that economic growth. The belief that the same technology which is partly to blame for the contemporary environmental and social challenges will solve them is a fantasy that is ingrained in conventional environmental policy. Such belief of course also fails to appreciate that 'technology' is a cultural fetish which conceals unequal social relations of exchange (Hornborg 2011). Technology, Hornborg explains, "refers to what is technically feasible to achieve at a given time and place, but remains largely oblivious to the extent to which a local increase in technological capacity is a

matter of shifting resources from one social category to another within global society" (Hornborg 2011:9). In *The Power of the Machine*, Hornborg (2001) develops the 'machine fetishism' argument further by arguing that machine technology is founded not so much on knowledge as on unequal exchange in the world-system. By promoting technological 'solutions,' ecomodernists are abetting and accelerating ecologically unequal exchange.

Another of the EM authors, Christopher Foreman, we are told, has written a book, *The Promise and Peril of Environmental Justice*, which "examines the limitations of environmental justice advocacy" (Asafu-Adjaye et al. 2015:4). This book criticizes the environmental justice movement as potentially harmful to the very minorities and low-income citizens it aspires to serve by, it claims, refusing to deal with the need for environmental priorities and trade-offs, and ignoring politically inconvenient 'facts' about environmental health risks (see Foreman 1998). In essence, Foreman is arguing that the equity and justice frame should play second fiddle to economic, political, and environmental 'priorities'. Reviewing the book, Ramo (2000) contends that Foreman, while highlighting legitimate challenges to the future of the environmental justice movement, "asserts several disturbing critiques of the environmental justice movement. ... Foreman's [analysis is] one-sided, or at least, [presents a] less-than-neutral presentation of environmental justice studies" (ibid., p. 1). Another reviewer, Krieg (2000) states that Foreman attempts to recast environmental injustices within technological issues and, in so doing, "downplays how social inequities manifest themselves in the form of environmental hazards and ignores the economic factors that lead to the adoption of these technologies" (p. 274).

When, finally, the EM states that "we write with the conviction that knowledge and technology, applied with wisdom, might allow for a good, or even great, Anthropocene" (Asafu-Adjaye et al. 2015:6), what is at the core of ecomodernism is clear. A "good Anthropocene," they say, requires that "humans use their growing social, economic, and technological powers to make life better for people, stabilize the climate, and protect the natural world" (ibid., p. 6). To even suggest that the Anthropocene can be 'good' is a concession to a particular perception of the ecological and human crisis that is the Anthropocene. The term Anthropocene is used to suggest that the Earth has entered a human-dominated geological epoch that is significantly different from the Holocene (the present interglacial natural geological epoch), a result of recent global anthropogenic environmental changes (cf. Steffen et al. 2007; Zalasiewicz et al. 2011). The significant alteration of the Earth system by *some groups* of human beings (and therefore its consequences for others) does not seem to concern these ecomodernists. Moreover, the Anthropocene is one of those de-politicizing concepts churned out by conventional environmental policy which suggest that "all humans" are historically and currently equally responsible for global environmental challenges such as climate change, rather than particular sections or groups in society, a conceptualization which ignores unequal global power structures

(cf. Malm and Hornborg 2014). As the EM reveals, ecological modernization is generally content with the current system of organizing the world and whatever changes are occurring. Nothing to it is 'broken' that needs 'fixing,' and in the very unlikely possibility that something could be wrong, human knowledge and technology will always fix it. They extol increased average life expectancy; reduced incidences and impacts of infectious diseases; increased resilience to extreme weather and natural disasters; decline in incidences of violence; increased liberal democracy, rule of law and freedom; and spread of personal, economic and political liberties as indicative of a global society well 'on track' (Asafu-Adjaye et al. 2015:4). Such 'general statistics' fail to capture global inequality by not specifying where the benefits are accruing, where the resource-base of the 'progress' is located, who is losing, and most importantly what is the root cause of the inequalities. They are part of the emerging discourse that, for example, perpetually tries to convince us that "Africa is Rising!"

Maarten Hajer (1995) reminds us that the ways in which environmental problems are socially constructed and propagated by different social groups, dominant and dominated, is what influences developments in environmental politics. Emerging since the 1970s, the policy discourse of ecological modernization, Hajer argues, does recognize that the ecological crisis is evidence of a flaw in the workings of modern society but, unlike the radical environmental movements of the 1970s, it suggests that environmental problems can be solved within the existing institutional arrangements (we don't need to change the system) and environmental management is a positive-sum game (all stand to benefit). If we recall Clapp and Dauvergne's (2011) four environmental worldviews, ecological modernization would fall within the market liberals and institutionalists. Such consensus-clad 'apolitical' or 'post-political' packaging of ecological modernization, Hajer (1995) believes, has made it attractive to politicians and policy-makers. He contends that the shift to ecological modernization is a general trend in the Western world, the same ideas, concepts, divisions and classifications emerging in different countries and international organizations such as the UN, OECD, or EU. But as EUE theory shows, some of which I highlight above and in Paper II, it is of course possible to illustrate the many kinds of issues such an ecomodernist approach does not address. In fact, Hornborg (2011) considers the *ideological pillars* of ecological modernization as interconnected illusions which mask EUE, postpone capitalism's inherent systemic crisis, and obstruct rational societal negotiations.[26] In Section 5 and Paper III, I focus on how

[26] Hornborg (2011:26) identifies these ideological pillars as i) fragmentation of scientific perspectives into bounded categories of 'technology', 'economy', and 'ecology', ii) the assumption that market prices equal reciprocity, iii) the illusion of machine fetishism, iv) representation of inequalities in societal space as developmental stages in historical time, and v) the belief that sustainable development is achievable through consensus.

issues of identity, ambivalence, conflict, antagonism, and power that are innate to society manifest themselves as environmental or economic problems.

4.3 Environmental Justice

On December 12, 1991, World Bank chief economist Lawrence Summers wrote an internal memo that leaked to the general public (See Box 4.1 below). The (in)famous memo has been analyzed from various perspectives. Summers' economic 'logic' and related neoliberal market theories are, in many cases, based on utilitarian microeconomic arguments referring to 'willingness to pay' and on the now discredited environmental Kuznets curve (EKC). To them, a fair market transaction may lead to an *unequal* but not *unjust* result – the participants 'freely choose' to transact. But no one would consciously choose such a level of exposure to environmental risk. Norgaard (2009) points out that economists have known for nearly two centuries that efficient market prices depend on the initial distribution of rights to factors of production. Economists, he explains, are thus quick to point out that they already know this when challenged, yet in practice, the economics profession ignores the past moral choices regarding how the initial distribution of rights influence the current market choices. The exposure to environmental hazards directly impinges on people's basic capabilities to attain some measure of well-being. Summers' memo serves as a perfect example of how notions of economic efficiency and win-win benefits espoused by neoclassical economics and practiced by conventional neoliberal policies are bereft of concerns with equity, fairness, and justice.

Public policy and administration have traditionally been guided by the faith in economic efficiency. Economic considerations and efficiency generally trump equity driven considerations—including considerations of environmental equity (Nijaki 2015). Little wonder that Summers was 'rewarded' for his interventions by being appointed the U.S. Treasury Secretary and later named president of Harvard University. Increasingly, however, social equity (fairness, justice, equality) is being seen as an important pillar of public policy. Moreover, other non-economic values, in particular the increasing focus on environmental impacts, are being addressed as important considerations in public administration. In *A Theory of Justice*, Rawls (1971) considers justice as fairness. He disagrees with utilitarian welfare economic policies by stating that the inviolable foundation of justice possessed by everyone cannot be overridden even by the welfare society. In other words, "justice denies that the loss of freedom for some is made right by a greater good shared by others. It does not allow that the sacrifices imposed on a few are outweighed by the larger sum of advantages enjoyed by many" (ibid. p. 3-4). To Rawls, a well ordered society – one that advances the good of its members and effectively regulates public conceptions of

justice - is characterized by two primary conditions: i) all societal members must acknowledge and know the principles of justice, and ii) social institutions should satisfy these principles. Nijaki (2015) identifies two different frames of environmental equity: sustainability and environmental justice. He considers the sustainability frame as focused on inter-generational equity while the environmental justice frame deals mainly with intra-generational equity. Although Nijaki's categorization may be misleading since the common understanding of sustainability incorporates both inter- and intra-generational equity, he is right that environmental equity entails both inter- and intra-generational considerations. Inter-generational equity strives to ensure that future generations are not deprived of enjoying the benefits of ecosystem services by the current generation, while intra-generational equity largely examines the distribution of environmental hazards and benefits among and between different geographically separated populations within the current generation.

The term 'environmental justice' is often used in relation to the unequal environmental burdens that are the hallmark of capitalist processes. It is concerned with why the poor, minorities, and indigenous people bear a heavy share of the environmental costs of 'development' (Costanza et al. 1997; Martinez-Alier et al. 2014). Environmental harms are injustices that are mediated through other justice claims (e.g. economic) and are contested in multi-scalar political and discursive spaces (Ramos 2015). Dating back to the 1970s in the United States, the environmental justice movement was largely spurred by increasing popular attention around health concerns attributable to the negative impacts of development (cf. Bullard 1990). The public began to understand the ramifications of policy decisions which, based on the kind of economic efficiency logic invoked by Lawrence Summers, exposed poor, people of color, and other ethnic minorities to a disproportionate share of environmental hazards and risks.

DATE: December 12, 1991
TO: Distribution
FR: Lawrence H. Summers
Subject: GEP

'Dirty' Industries: Just between you and me, shouldn't the World Bank be encouraging MORE migration of the dirty industries to the LDCs [Less Developed Countries]? I can think of three reasons:

1) The measurements of the costs of health impairing pollution depends on the foregone earnings from increased morbidity and mortality. From this point of view a given amount of health impairing pollution should be done in the country with the lowest cost, which will be the country with the lowest wages. I think the economic logic behind dumping a load of toxic waste in the lowest wage country is impeccable and we should face up to that.

2) The costs of pollution are likely to be non-linear as the initial increments of pollution probably have very low cost. I've always thought that under-populated countries in Africa are vastly UNDER-polluted, their air quality is probably vastly inefficiently low compared to Los Angeles or Mexico City. Only the lamentable facts that so much pollution is generated by non-tradable industries (transport, electrical generation) and that the unit transport costs of solid waste are so high prevent world welfare enhancing trade in air pollution and waste.

3) The demand for a clean environment for aesthetic and health reasons is likely to have very high income elasticity. The concern over an agent that causes a one in a million change in the odds of prostate cancer is obviously going to be much higher in a country where people survive to get prostate cancer than in a country where under 5 mortality is 200 per thousand. Also, much of the concern over industrial atmosphere discharge is about visibility impairing particulates. These discharges may have very little direct health impact. Clearly trade in goods that embody aesthetic pollution concerns could be welfare enhancing. While production is mobile the consumption of pretty air is a non-tradable.

The problem with the arguments against all of these proposals for more pollution in LDCs (intrinsic rights to certain goods, moral reasons, social concerns, lack of adequate markets, etc.) could be turned around and used more or less effectively against every Bank proposal for liberalization.

Source: Whirled Bank Group (2001)

Box 4.1:
Lawrence Summers' Memo

Between October 24 and 27, 1991, delegates to the First National People of Color Environmental Leadership Summit, held in Washington D.C., drafted and adopted 17 principles of Environmental Justice (Box 4.2). Since then, these Principles have served as a defining document for the growing global environmental justice movement (cf. UCC, nd). It demands that public policy be based on mutual respect and justice for all, free from any form of discrimination or bias, and the right of victims of environmental injustice to receive full compensation and reparations. To them, the 'ecological debt' should be 'paid,' with the victims playing a significant role in determining what form or type the 'payment' should take. The environmental justice movement can thus be understood as broadly aimed at challenging capitalist economic efficiency rationalities from a social equity and justice perspective.

Three dimensions of justice claims can be identified: redistribution, recognition, and representation (Ramos 2015). Nijaki (2015) divides the principles of environmental

justice into distributive and cumulative (or corrective) forms of justice. Nijaki's categorization can be integrated into Ramos's three dimensions of justice, distributive being equivalent to what the latter calls redistribution while cumulative approximates representation (and participation) in decision-making processes. *Redistribution* involves justice claims over economic and material resources. Amartya Sen's (1999) capabilities approach to development is one way of thinking about distributive environmental justice. It is centered on the fair distribution of capabilities in order to achieve well-being, capabilities being the *power* and *resources* necessary in order for individuals to exercise their self-determination. The claims for reparations founded on the EUE-derived concept of 'ecological debt' are not only attempts at 'correcting' the asymmetric resource flows, they are intended to address this aspect of justice – to enhance the capabilities of the global South to pursue the good life. The *recognition* dimension of justice involves claims regarding social and cultural status. This aspect of environmental justice was at the root of the environmental justice movement, which began as protests against 'environmental racism': the discrimination of populations on the basis of racial, ethnic, or cultural identities.

Through its framing as primarily an economic problem generated by the structure and organization of the world-economy, the discourse on ecologically unequal exchange has tended to neglect racism and such identity-related analytical perspectives and dimensions of justice. I argue this point in more detail in Paper III. Among the issues I raise are, for example, if it is possible that the contemporary dominance of (Western) capitalism and its treadmill logic of endless accumulation based on unequal exchange is a consequence of the non-recognition and non-incorporation into Marxian theory of other cultures' ways of organizing society. Cognitive injustice, the failure to recognize other people's ways of knowing, Santos (2014) contends, is the basis of all other dimensions of justice. *Representation*, the third dimension of justice, involves demands for participation in institutional and political power centers. In the context of international trade and EUE, it involves concerns about influence over international politico-economic institutions such as the World Bank, IMF, UN, WTO, and nation-states, which are seen as mainly serving the interests of affluent core countries and profit-oriented MTNCs rather than those of the poor, indigenous groups, the environment, or future generations. Indeed, as I argue in Paper II, the unequal political representation in institutions that govern the world-economy, by tilting the playing field in favor of the global North, is a key factor explaining why EUE occurs.

WE, THE PEOPLE OF COLOR, gathered together at this multinational People of Color Environmental Leadership Summit, to begin to build a national and international movement of all peoples of color to fight the destruction and taking of our lands and communities, do hereby re-establish our spiritual interdependence to the sacredness of our Mother Earth; to respect and celebrate each of our cultures, languages and beliefs about the natural world and our roles in healing ourselves; to ensure environmental justice; to promote economic alternatives which would contribute to the development of environmentally safe livelihoods; and, to secure our political, economic and cultural liberation that has been denied for over 500 years of colonization and oppression, resulting in the poisoning of our communities and land and the genocide of our peoples, do affirm and adopt these Principles of Environmental Justice:

The Principles of Environmental Justice (EJ)

1) **Environmental Justice** affirms the sacredness of Mother Earth, ecological unity and the interdependence of all species, and the right to be free from ecological destruction.

2) **Environmental Justice** demands that public policy be based on mutual respect and justice for all peoples, free from any form of discrimination or bias.

3) **Environmental Justice** mandates the right to ethical, balanced and responsible uses of land and renewable resources in the interest of a sustainable planet for humans and other living things.

4) **Environmental Justice** calls for universal protection from nuclear testing, extraction, production and disposal of toxic/hazardous wastes and poisons and nuclear testing that threaten the fundamental right to clean air, land, water, and food.

5) **Environmental Justice** affirms the fundamental right to political, economic, cultural and environmental self-determination of all peoples.

6) **Environmental Justice** demands the cessation of the production of all toxins, hazardous wastes, and radioactive materials, and that all past and current producers be held strictly accountable to the people for detoxification and the containment at the point of production.

7) **Environmental Justice** demands the right to participate as equal partners at every level of decision-making, including needs assessment, planning, implementation, enforcement and evaluation.

8) **Environmental Justice** affirms the right of all workers to a safe and healthy work environment without being forced to choose between an unsafe livelihood and unemployment. It also affirms the right of those who work at home to be free from environmental hazards.

9) **Environmental Justice** protects the right of victims of environmental injustice to receive full compensation and reparations for damages as well as quality health care.

10) **Environmental Justice** considers governmental acts of environmental injustice a violation of international law, the Universal Declaration On Human Rights, and the United Nations Convention on Genocide.

11) **Environmental Justice** must recognize a special legal and natural relationship of Native Peoples to the U.S. government through treaties, agreements, compacts, and covenants affirming sovereignty and self-determination.

12) **Environmental Justice** affirms the need for urban and rural ecological policies to clean up and rebuild our cities and rural areas in balance with nature, honoring the cultural integrity of all our communities, and provided fair access for all to the full range of resources.

13) **Environmental Justice** calls for the strict enforcement of principles of informed consent, and a halt to the testing of experimental reproductive and medical procedures and vaccinations on people of color.

14) **Environmental Justice** opposes the destructive operations of multi-national corporations.

15) **Environmental Justice** opposes military occupation, repression and exploitation of lands, peoples and cultures, and other life forms.

16) **Environmental Justice** calls for the education of present and future generations which emphasizes social and environmental issues, based on our experience and an appreciation of our diverse cultural perspectives.

17) **Environmental Justice** requires that we, as individuals, make personal and consumer choices to consume as little of Mother Earth's resources and to produce as little waste as possible; and make the conscious decision to challenge and reprioritize our lifestyles to ensure the health of the natural world for present and future generations.

More info on environmental justice and environmental racism can be found online at www.ejnet.org/ej/

Delegates to the First National People of Color Environmental Leadership Summit held on October 24-27, 1991, in Washington DC, drafted and adopted these 17 principles of Environmental Justice. Since then, the Principles have served as a defining document for the growing grassroots movement for environmental justice.

Source: Ejnet (1991)

Box 4.2:
Principles of environmental justice

5 Epistemology: Wider Connections

The Ricardian international division of labor through which ecologically unequal exchange (EUE) manifests itself can be viewed as a social process of "*Othering*." This suggested conception of EUE is the basis of my argument in Paper III. Gayatri Spivak (2010), one of the leading postcolonial scholars, characterizes the contemporary international division of labor as the gradual emergence of a new *subaltern*. However, this perspective has not been explored to any length by EUE scholarship. While discussing environmental justice under Section 4.3 above, I highlighted *recognition* as an important dimension of justice. Stoler (2013) argues that despite environmental justice acknowledging the relationship between colonial rule and degraded environments, little of this analysis has made a direct link to the corpus of postcolonial scholarship or to postcolonial situations.[27] I argue that EUE scholarship should directly connect with and possibly learn from postcolonial, decolonial, feminist and critical social theories and perspectives as they share a common *political* struggle and concern for the subaltern 'other'. In short, the periphery is the Other of the core.

5.1 The Concept of "Otherness"

Sociologists analyze how social identities are constructed through the concept of 'Other'. The construction and representation of majority and minority identities within society are controlled by those groups that have greater political power. This questions the often taken-for-granted view that identities are natural or innate. While psychology concerns itself with individual characteristics, sociologists focus on social identities, how individuals and groups internalize established social categories within their societies, such as their cultural (or ethnic) identities, gender identities, class

[27] "Postcolonial studies" is a loosely defined inter-disciplinary field that deals with colonial rule and seeks to deconstruct colonial discourses and thought patterns that continue to influence the contemporary (Fischer-Tine 2010). Anne McLintock (1992) has criticized the term 'post-colonial' for, despite challenging Western historicism and a Cartesian view of the world, "nonetheless re-orient[ing] the globe once more around a single, binary opposition: colonial/ post-colonial" (p. 85). One could say that 'post-colonial' is one of those terms which, like 'degrowth', constantly fall in the shadow of what they wish to critique.

identities, and so on. These social categories shape our ideas about who we think we are, how we want to be seen by others, and the groups to which we belong. In *Modernity and Ambivalence*, Bauman (1991) argues that social identities are set up as dichotomies:

> "In dichotomies crucial for the practice and the vision of social order the differentiating power hides as a rule behind one of the members of the opposition. The second member is but *the other* of the first, the opposite (degraded, suppressed, exiled) side of the first and its creation. Thus abnormality is the other of the norm, deviation the other of law-abiding, illness the other of health, *barbarity the other of civilization*, animal the other of the human, *woman the other of man*, stranger the other of the native, enemy the other of friend, 'them' the other of 'us', insanity the other of reason, foreigner the other of the state subject, lay public the other of the expert. *Both sides depend on each other, but the dependence is not symmetrical.* The second side depends on the first for its contrived and enforced isolation. The first depends on the second for its self-assertion" (Bauman 1991:14, emphasis mine).

How we achieve a sense of identity is thus linked to ideas of similarity and difference, what Bauman terms *ambivalence*. Social identities are by nature relational because groups typically define themselves relative to others (Okolie 2003). Because identity is rarely claimed or assigned for its own sake, Okolie notes, such definitions have purposes and consequences as they are tied to material and/or symbolic rewards and punishment. For this reason, identities are contested since power is involved, with notions of superiority and inferiority embedded in particular identities. Social identities therefore represent an established social order or hierarchy in which certain groups are socially constructed as being superior to others, and are thus a reflection of unequal power relations and antagonism. The term *subaltern* takes the notion of Other further to suggest that, in many instances, the dominated Other is also simultaneously constructed as socially, politically, economically, and historically outside and of a lower rank in the hegemonic power structure of the dominant group (cf. Louai 2012; Guha 1982). This Othering, Bauman (1991) explains, is at the core of modernity:

> "The typically modern practice, the substance of modern politics, of modern intellect, of modern life, is the effort to exterminate ambivalence: an effort to define precisely - and to suppress or eliminate everything that could not or would not be precisely defined. Modern practice is not aimed at the conquest of foreign lands, but at the filling of the blank spots in the *compleat mappa mundi*" (p.7-8).

If we accept and apply Bauman's perspective to the contemporary international division of labor, we begin to appreciate that EUE is not necessarily "the conquest of foreign lands" but is rather an effort to exterminate ambivalence, to suppress or eliminate the Other. Postcolonial and feminist scholars have long understood and

applied such a perspective in their analysis of the contemporary world-system. In *Can the Subaltern Speak?* Spivak (2010:41-43) describes the contemporary international division of labor as "a displacement of the divided field of nineteenth-century territorial imperialism" (p.41) and the "gradual emergence of the new subaltern in the New World Order" (p.41). In doing so, Spivak directly and seamlessly connects contemporary global inequality with 'past' colonial imperialism through the commonality of their motivations and the creation of the subaltern other. This is how she describes the emergence of the new subaltern:

> "Put in the abstractions of capital logic, in the wake of industrial capitalism and mercantile conquest, a group of countries, generally first-world, were in the position of investing capital; another group, generally third world, provided the fields for investment, both through the subordinate indigenous capitalists and through their ill-protected and shifting labor force. In the interest of maintaining the circulation and growth of industrial capital (and of the concomitant task of administration within nineteenth-century territorial imperialism), transportation, law, and standardized education systems were developed – even as local industries were destroyed or restructured, land distribution was rearranged, and *raw material was transferred to the colonizing country*. With so-called de-colonization, *the growth of multinational capital*, and the relief of the administrative charge, "development" did not now involve wholesale state-level legislation and establishing education systems in a comparable way. This impedes the growth of consumerism in the former colonies. With modern telecommunications and the emergence of advanced capitalist economies at the two edges of Asia, *maintaining the international division of labor serves to keep the supply of cheap labor in the periphery*. The implosion of the Soviet Union in 1989 has smoothed a way to the financialization of the globe. Already in the mid-seventies, the newly electronified stock exchanges added to the growth of telecommunication, which allowed global capitalism to emerge through *export-based subcontracting* and post-fordism. Under this strategy, *manufacturers based in developed countries subcontract the most labor intensive stages of production, for example, sewing or assembly, to the Third World nations where labor is cheap*. Once assembled, the multinationals re-import the goods – under generous tariff exemptions – to the developed country instead of selling them to the local market" (Spivak 2010:41-42, emphasis mine).

Spivak's statement is quite revealing. It suggests that 'capital logic', which I refer to as the *economic* framing of the contemporary international division of labor and EUE, can be an 'abstraction' which can mislead or 'hide' other possible interpretations of the world-system. She states that under colonialism, aided by among others "standardized education systems" (read science), raw materials were being transferred to the colonizing European countries. This much we already know. After this 'colonial' period, a new order characterized by the market and financialization, i.e. neoliberalism, took over and the transfer of resources (including labor) from the global South to the North continues through "export-based contracting" and the

exportation of raw and semi-processed materials. Noting that "human labor is not, of course, intrinsically 'cheap' or 'expensive'" (Spivak 2010:42) – a reference to the anthropocentric/cultural nature of monetary valuation - Spivak explains that "In the post-Soviet world, the Bretton Woods organizations, together with the United Nations, are beginning to legislate for a monstrous North/South global state which is coming into being as micrologically as the trade-controlled colonial state" (ibid. p.42). She thus likens the modern world-system or *Empire* (see Hardt and Negri 2000) to the colonial state, which was controlled by the European center.

As I elaborate in Paper II, in the 'post-colonial' era Spivak is referring to the treadmill logic of capitalism through which capital, supported by 'free-trade' ideologies and policies, and using politico-economic institutions such as the Bretton Woods institutions, facilitate the asymmetric flows of matter-energy from the periphery to the core. In referring to human labor (somatic energy) as not intrinsically 'cheap' of 'expensive', she is focusing attention to the difference between the physical (thermodynamic) and economic (cultural) which should be analytically separated and not conflated through the standard called money. These arguments, as we have seen throughout this thesis, are similar to those raised by EUE theory. What is different is that Spivak does not see them merely as 'innocent' economic processes but rather as conditions for the emergence of a 'new' subaltern (the 'old,' we have to assume, is the subaltern 'other' under colonialism). To underscore her point that contemporary EUE is a social process of constituting the 'other', she states that "as the North continues to ostensibly 'aid' the South – as formerly imperialism 'civilized' the New World – the South's crucial assistance to the North in keeping up its resource-hungry lifestyle is forever foreclosed" (Spivak 1999:6). The assistance provided by the South in keeping the North's resource-hungry lifestyle can only be interpreted as referring to the EUE phenomenon, even if postcolonial theory in itself has no methodology for validating such claims. Spivak's linking of the colonial 'civilizing' of the South by the North to contemporary EUE could not be clearer. To her, and this is the feminist twist, the female (especially in the global South) is worse off in this new dispensation: "If, in the context of colonial production, the subaltern (gender-unspecified) has no history and cannot speak, the subaltern as female is even more deeply in shadow" (Spivak 2010:41). Consideration of the 'other' in the division of labor is, of course, not new. To Marx it was economic class identity (the bourgeoisie vs. proletariat), a reflection of his focus on Europe. From a contemporary North/South divide class would still feature but more pronounced would be a racial or ethnic dimension of Otherness, and from a feminist/gender perspective it would be heteronormativity. Reflecting on EUE from an Otherness perspective leads to an ethics and human rights approach. That is, how do we treat the people (and their environments) we consider different from us? Birla (2010) argues that Spivak's work exhorts us to, instead of "speaking for," be responsive to the other without seeking to exterminate ambivalence or demand resemblance as the basis for recognition.

Marxist critics such as Spivak and Fredric Jameson (see below), Eatough (2015) contends, attempt to map literature onto the geography of a capitalist world-system. Such writers, Eatough argues,

> "took their inspiration from [Frantz] Fanon's dialectical reading of the colonial encounter in Wretched of the Earth and Black Skins, White Masks, where Fanon theorizes that capitalism in its imperial guise operates through the construction of opposing ontological categories: white/black, human/subhuman, and civilization/barbarity. For Jameson and his fellow Marxist critics, Fanon's insight can be extended to global capitalism as a whole, which should be understood, they argue, as a "totality" in the Hegelian sense: that is, as a single field bound together through the dialectical play of constitutive opposites. […] As such, it is not merely different types of commodities and modes of production that transform when one moves from 'First' to 'Third' World, but the very epistemological and ontological coordinates of culture, society, and the economy" (p. 597-598).

5.2 A Political Foundation of EUE

Critical social theory has witnessed a shift towards a 'culturalization' of the economy in a manner that addresses society as a totality. Sometimes drawing on Freud's psychoanalysis, this shift has seen ongoing concern and efforts to modify Marx's analysis by mounting a critique of culture and society beyond the critique of political economy by treating culture not as ancillary (superstructure), as Marx was prone to, but as the crucible in which the modern world-economy and world-system resides (Dant 2003). Marxists consider the economy's production relations as shaping its relations of exchange and distribution, and as the basis of the organization of society (Burkett 2005). Such orthodox Marxist theory perpetuates the conception of the economic as "ultimately determining" the superstructures of society. The *cultural* critique of Marxism challenges such economic determinism and is mounted by, for example, Fredric Jameson (1981), who argues for the priority of the *political*. Jameson "conceives of the political perspective not as some supplementary method, not as an optional auxiliary to other interpretive methods current today—the psychoanalytic or the myth-critical, the stylistic, the ethical, the structural—but rather as the absolute horizon of all reading and all interpretation" (ibid. p.1). To him, such an approach allows us to weigh a Marxist interpretation against other interpretive methods with which Marxism "must compete in the 'pluralism' of the intellectual marketplace" (ibid. x). Such Marxist criticisms can be seen as part of the "ontological turn".

Cultural analysts, according to Jameson (1981), can chose to study what he calls "the 'objective' structures of a text," i.e. its historical and situational specificity. On the other hand, focus can be on the *interpretive categories* or *codes* through which such

texts are read and received – what he calls the *Political Unconscious*. The Political Unconscious is premised on the dynamics of the act of interpretation and presupposes that texts are read through layers of previous interpretations or reading habits developed by such prior interpretive traditions. The reading of the cultural text is thus not 'original' but is rather a 'metacommentary' that "rewrit[es] a given text in terms of a particular interpretive master code" (ibid. x). Although Jameson criticizes Marx's economic determinism, he stresses the dialectical dictum to *always historicize* as most famously captured by Marx's contention that all human history is characterized by persistent and uninterrupted class struggles – the 'Otherness' of oppressor and oppressed: "It is in detecting the traces of that uninterrupted narrative, in restoring to the surface of the text the repressed and buried reality of this fundamental history, that the doctrine of a political unconscious finds its function and its necessity" (ibid., p.4). Such a Political Unconscious perspective, Jameson argues, allows us to recognize that everything is social and historical. This way, we are better equipped to explore different methods through which to unmask cultural artifacts as socially symbolic acts. That is, everything is, "in the last analysis," political. A Political Unconscious is therefore the cultural lens through which we interpret and interact with reality. It is, in a sense, the 'blind spots' which we (individually and as a society) may not be aware of or simply take for granted, but which nevertheless influence our view of reality.

Contemporary hegemonic discourses of ecological modernization and neoliberalism embody such a Political Unconscious. Hajer (1995) contends that environmental discourse is time- and space-specific, and is governed by a specific modelling of nature "which reflects our past experience and present preoccupations" (p.17). Any understanding of the (socioecological) environment, he argues, "is based on representations, and always implies a set of assumptions and (implicit) social choices that are mediated through an ensemble of specific discursive practices" (ibid. 17). The dynamics of environmental politics therefore cannot be understood without considering the discursive practices that guide our perception of reality. Such discursive practices and filters, I submit, include cultural identities, traditions, and influences that are at the core of the Political Unconscious. From this perspective, we can ask what are the "cultural preoccupations" of the North vis-a-vis the South, and how do such preoccupations influence global resource distribution and environmental change? In *A Brief History of Neoliberalism*, Harvey (2005) argues that neoliberalization can be interpreted either as i) a utopian theoretical design project to reorganize international capitalism or, ii) a political project to restore (economic) class power and domination. To him, the latter objective has triumphed in practice because "the theoretical utopianism of neoliberal argument has […] primarily worked as a system of justification and legitimation for whatever needed to be done to achieve this goal [restoration of elite power]" (ibid. 19). Neoliberalism, according to Harvey, has from the very beginning been a project to restore class power. This, he says, is not to deny the role ideas play in bringing about historical-geographical change, but is

rather a pointer to how ideas become hegemonic or commonsensical through a *cultural* route. For any way of thought or ideology to become dominant, Harvey contends, it has to be advanced in a manner that appeals to our cultural values and desires, intuitions and instincts, and social settings. By taking the political ideals of individual freedom and human dignity as fundamental tenets, Harvey (2005) argues, the founding figures of neoliberalism "chose wisely," for these were indeed compelling and seductive Western ideals. But, as Harvey cautions, cultural and traditional values and fears can be mobilized to mask other realities: "Political slogans can be invoked that mask specific strategies beneath vague rhetorical devices" (ibid. 39). For this reason, he argues that in order to understand society, particularly how hegemonic discourses become so, we must learn to extract political meanings from their cultural skins. I apply such a perspective in Paper III in arguing that EUE, which has so far been conceptualized as simply a consequence of the structure of the capitalist world-economy, could in fact be masking deep-seated cultural, racial, ethnic, and androcentric notions of superiority on which we should focus our attention. We must, to use the title of Tlostanova and Mignolo's (2012) book, "learn to unlearn" what culture has taught us, to become conscious of our Political Unconscious.

Ideologies as political discourses are aimed at securing people's voluntary consent regarding contestable political issues. According to the classical Marxist 'false consciousness' perspective, ideologies are discourses that promote *false ideas*, and because people believe them to be true, they inadvertently reproduce the existing status quo. According to this understanding, to undermine an ideology it is enough to expose the concealed truth(s), after which subjects will become aware of the shortcomings of their current regimes and be motivated to change them (Sharpe 2010). Of course, Marxist critique also stresses that changing ideas alone is not enough. We must also change material relationships in order to truly transform society. Slavoj Žižek has a different view on the Marxist operation of ideologies. In *Sublime Object of Ideology*, Žižek (1989) argues that today, typical Western subjects are the dupes of what he calls 'ideological cynicism.' To him, any successful ideology allows subjects to have *ideological disidentification*, which is connected to the psychoanalytic split between *conscious awareness* and *unconscious beliefs* and the crucial distinction between knowledge and belief (Sharpe 2010). According to Žižek (1989), ideology today does not operate according to the Marxist interpretation that 'they do not know it, but they are doing it,' but rather 'they know very well what they are doing, but they are doing it anyway' (ibid. pp.28-30). To illustrate his point, Žižek states that "when individuals use money, they know very well that there is nothing magical about it – that money, in its materiality, is simply an expression of social relations…so, on an everyday level, the individuals know very well that there are relations between people behind the relations between things" (ibid. 28). Žižek's statement supports my contention in Paper III that those of us who have been studying EUE from the old Marxist 'false consciousness' perspective, by seeking to

'reveal' that monetary exchange masks (unequal) material (biophysical) relations, may be mistaken. For if, as Žižek argues, the masses know this fact, why would we assume that the elite neoliberal economists don't? Using the notion of freedom, Žižek explains this "enlightened false consciousness" thus: "they know that their idea of Freedom is masking a particular form of exploitation, but they still continue to follow this idea of Freedom" (ibid. 30). As Harvey (2005) explains, the ideas of individual freedom and human dignity were used to install neoliberalism by its architects. Because different cultural groups 'know' their prejudices against their 'Other', Zizek's perspective is a bold and straightforward restatement of Jameson's Political Unconscious. A Žižekian reading of EUE therefore suggests that the West knows that its capitalist neoliberal ideologies are exploiting the Global South, 'but they are doing it anyway.' This is the *political foundation* upon which EUE must be conceptualized.

Lawrence Summers was obviously aware of "health impairing pollution" and that the toxic dumps would cause cancer in the people of the developing countries. He was also aware of the arguments against his proposals (see last paragraph of Box 4.1) but was more concerned with the success of the World Bank's liberalization policies which, as we have seen, are primarily intended to restore and maintain elite power. To think that neoliberal economists and the politicians who follow their advice do not know the consequences of their actions is a delusion. That is why the categorization as 'ecocide' of such deliberate neoliberal policies (and the economic theories which espouse them) which harms the environment and people is justified and they should be treated as criminal offenses. In *The Crimes of the Economy: A Criminological Analysis of Economic Thought*, Ruggiero (2013) examines a variety of economic schools of thought and argues that each one of them, from Mercantilism to neoliberalism, justifies or encourages the social harm caused by economics. In doing so, Ruggiero goes beyond conventional definitions of crime which are insufficient to deal with the crimes of the powerful and of economic policy.

An understanding of EUE from the Žižekian perspective is, however, under threat from the many apolitical, post-political, and de-politicizing concepts such as 'democracy,' 'resilience,' 'sustainable development,' 'Anthropocene,' etc. which litter contemporary discourse. Chantal Mouffe (2005) takes issue with the common sense view within Western societies that their current state of 'development' constitutes a great progress in the evolution of humanity and that conflicts are obsolete and consensus can now be attained through dialogue. She distinguishes between 'the political" - a space of power, conflict, and antagonism, antagonism being constitutive of human societies - and 'politics,' i.e. the set of practices and institutions which create order by organizing human coexistence in the antagonistic context of the political. In examining the consequences of the negation of antagonism, Mouffe (2005) contends that visualizing the aim of democratic politics in terms of consensus and reconciliation is mistaken and dangerous. Democracy, she explains, has been constructed on idealized principles of human sociability and non-violence such that

anyone who challenges this optimistic view is automatically perceived as enemies of democracy, enemies of "progress", or anti-West. To Mouffe, creation of vibrant 'agonistic' public spheres of contestation where different hegemonic projects can be confronted is the *sine qua non* of an effective democracy. This stance informs my critique of conventional ecological modernization concepts of 'mainstreaming' and 'resilience' in Paper II as, despite possible good intentions, supportive of the existing unequal power structures. It also inspires my stated aim throughput this thesis to offer intellectual support to social movements. What the post-political camp wishes is to consign us to a 'life without idea,' comprising, in that sense, a counter-revolution to the hopes of the poor majority. 'Idea,' Diken (2012) contends, is that which enables us to contemplate another possible and better world. Without such an imaginary, social life becomes bare repetition, an endless Sisyphean reiteration of the same. Life without idea, Diken argues, is the ambition to suppress this transcendent possibility which only becomes alive through social upheaval. Revolution, as Deleuze (1994:208) posits, is at the core of social critique and of society itself:

> "Social problems can be grasped only by means of a 'rectification' which occurs when the faculty of sociability is raised to its transcendent exercise and breaks the unity of fetishistic common sense. The transcendent object of the faculty of sociability is revolution. In this sense, revolution is the social power of difference, the paradox of society, the particular wrath of the social Idea."

Revolt, therefore, is essential to a good and sustainable society. Said (1994) argues that it is the spirit in opposition rather than in accommodation that should interest the intellectual. "The challenge of intellectual life is to be found in dissent against the status quo at a time when the struggle on behalf of underrepresented and disadvantaged groups seems so unfairly weighted against them" (ibid. xvii). In *Pedagogy of the Oppressed*, Freire (1970) argues that any situation in which "A" objectively exploits "B" or hinders their pursuit of self-affirmation is one of oppression, and that "such a situation in itself constitutes violence, even when sweetened by false generosity, because it interferes with the individual's ontological and historical vocation to be more fully human" (p. 55). In other words, and contrary to the common understanding of violence, the mere establishment of an exploitative relationship sets in motion violence. Rob Nixon's (2011) book *Slow Violence and the Environmentalism of the Poor* puts this in context. Freire (1970:55) goes on to state that

> "[v]iolence is initiated by those who oppress, who exploit, who fail to recognize others as persons - not by those who are oppressed, exploited, and unrecognized. It is not the unloved who initiate disaffection, but those who cannot love because they love only themselves. It is not the helpless, subject to terror, who initiate terror, but the violent, who with their power create the concrete situation which begets the "rejects of life." It is not the tyrannized who initiate despotism, but the tyrants. It is not the despised who initiate hatred, but those who despise. It is not those whose humanity is denied them who negate humankind, but those who denied that humanity (thus negating their own as well).

5.3 Science and Inequality

Modern science is a cultural artifact, a product of Western civilization dating back to the era generally known as the Enlightenment. The Enlightenment was an era in the development of Western culture and thought which supposedly swept away medieval world-views based on religion and other cultural beliefs. One of its products was the emergence of modern science, whose benefits to humanity are undeniable. But science does not always have such benevolent consequences. In Paper III, I ask: Does modern science suffer from a Political Unconscious? Does it contribute to the restoration of elite power? Does it weave a spider's web through which we fail to appreciate Žižek's 'revelation'? Does it contribute to and/or sustain EUE? Science is supposed to shine its 'light' into the 'darkness' of religion and cultural beliefs. Distinguishing between "common sense" and "good sense", Gramsci (1971) contends that the former is constructed out of long-standing practices of cultural socialization often rooted deep in regional or national traditions, and is different from the latter, which can be constructed out of critical engagement with the issues of the day. Gramsci considers philosophy as critique which supersedes religion and common sense, coinciding with "good" as opposed to "common" sense. While admitting that common sense (or culture) is not rigid but continually changing and enriching itself with scientific ideas, he is however adamant that common sense and religion "cannot constitute an intellectual order." This is "because they cannot be reduced to unity and coherence even within an individual consciousness, let alone collective consciousness… [unless by] 'authoritarian' means" (ibid., p.631). Gramsci is suggesting that science and culture can be separated, science influencing and modifying culture but not the other way round. Such an understanding fails to appreciate that science itself is cultural. Not only did modern science emerge from Western cultural development and is therefore inexorably influenced by it, science has almost become a common sense part of contemporary society that is taken for granted, not to be questioned.

Sandra Harding (2006:ix) notes that "although the benefits of modern Western sciences have disproportionately been distributed to people like *us* [the elite, the rich, the West], their costs have disproportionately been borne by the economically and politically most vulnerable groups around the world." But the observation that science can be biased in apportioning its benefits and harms among different social groups is not easily appreciated. How science contributes to social inequality has been analyzed from different angles. Costanza et al. (1997) usefully argue that if we believe that science has indeed driven the technological and institutional changes that have brought 'development,' then surely science must also be partly responsible for the negative environmental and human consequences of that development. Next, we need to ask ourselves whether the negative and positive consequences of development are evenly distributed globally or not, to which the answer from an EUE perspective is an emphatic no. Scientific knowledge production is not only cultural, it is produced from particularistic prisms, interests, and positions that are always embodied and part of a complex web of power relations (McAlister 2010). Livingstone (2003) painstakingly shows how scientific knowledge production is inherently geographical, a reflection of its localized nature. Although culture exists within a specific physical environment, the science-culture-geography nexus is illuminated by Levi-Strauss (1972:19), who emphasizes that the scientist engages in a dialogue with "a particular relationship between nature and culture" which depends on the particular historical moment as well as the material resources at his disposal. All knowledge production, therefore, is indigenous.

Because science and scientific knowledge production is a social activity ruled by a plurality of values (de Molina and Toledo 2014), producing science which is free from any socio-cultural values and interests is not only difficult in practice but impossible in principle. Harding (2006) points out that male supremacy, racism, class exploitation, and colonial and imperial exploitation and domination still permeate Western sciences. To identify these forces, she posits, focus should be put on analyzing the socio-political processes which result in scientific and technological policies which damage both humans and the environment. Connell (2007) draws our attention to the use of science in the Othering of the non-European by the non-inclusion of Southern ways of knowing, ideas, and intelligentsia into the episteme of scientific theory. Such *epistemicide* (Santos 2014) explains why it is ultimately the very ontology of modern sciences which generates inequitable effects (Harding 2006). These criticisms of science are genuine grounds upon which we can examine its Political Unconscious.

6 Conclusion

The Global South, that is, most of Africa, Latin America, and parts of Asia, do not suffer from a 'resource curse'. The resource richness of such countries and regions is what Adam Smith and David Ricardo enviably called absolute advantage, advising other less endowed nations to strategize on how to secure a piece of the pie through the concept of comparative advantage. This is how the idea of an international division of labor and 'free trade' was born. The 'invisible hand' that imperils the periphery's development is the global capitalist system of exchange whose fulcrum is unequal exchange. This exploitative system is supported by a choreographed mix of hegemonic yet anti-realist ideologies, theories, politico-economic institutions, cultural identities, and pseudo-science. The couching of unequal power relations that ensure a net transfer of resources from the periphery to benefit the core industrialized countries in terms such as 'resource curse' only serves to mask ecologically unequal exchange (EUE). Exposing such illusions has been the primary objective of this thesis.

Ecologically unequal exchange does occur. Several approaches and methods to empirically assess the occurrence of EUE which apply biophysical metrics rather than money have been reviewed. Studies which apply such methods and their demonstration of EUE have been highlighted. A new LCA-based methodology with the potential to add to this body of knowledge has been proposed in Paper I. In Paper II, I have highlighted the various processes and mechanisms through which EUE occurs and various options available to policymakers and social movements. These processes include the treadmill logic of capitalism, the 'free-market' ideology, the modern nation-state and other international politico-economic institutions, and monetary valuation, which confuses economics and thermodynamics. Such exploitative structures that constitute the contemporary world economic system raise equity and justice issues without which, I have argued, genuine sustainable development will remain a mirage. In Paper III, I have been critical of the current economic conceptualization of EUE and have suggested a *complementary* political conceptualization. This must not be construed as a rejection of the very important work EUE research does in revealing the unequal transfer of resources from the periphery to the core and how. Far from it. What I have hoped to achieve with my critique is twofold. First is to broaden the horizon of EUE research to cover areas that hitherto have been neglected. Doing so can only enhance EUE research. Second, I sought to re-politicize EUE in an effort to make it more useful and practical to social

movements. If, as I have posited in Section 5 and Paper III, decision-makers in the global North *know very well* that their capitalist system and ideologies of 'freedom' and 'democracy' are exploiting and imperiling the development of the global South, but continue to support and propagate them anyway, how can such an understanding influence social movements (in both the global North and South)? The take-home message from this is that EUE is a political problem which can only be solved politically. To arrive at that political solution will of course require all kinds of analysis - economic, environmental, and socio-cultural.

One question that I have been asked in the course of researching on and writing this thesis is whether EUE is advocating for a withdrawal from the exploitative contemporary global system of exchange. I think this is indeed one of two options available to those who truly wish for genuine change. The other is to completely change the current capitalist system of exchange and 'install' another 'better' one. There are already discussions and proposals as to the nature of such a new possible world. No one is under the illusion that achieving that new world will be an easy road. Half of the world's population is already deeply embedded in the global economy and are interconnected through markets (Norgaard 2009). But, depending on one's ideological stand or position in the global 'food chain', it is definitely worth a try. The second option is to retreat from the global circuits of production and exchange to more localized exchange systems based on the principle of self-sufficiency. The substitution of market relations for what used to be done within households and between friends, Norgaard argues, has reduced diverse relationships and moral obligations which are the essence of community to mutual greed. To be fair, those who have benefitted from the capitalist system can retain it, while those who have not must have the freedom to choose something else. It should be possible to have multiple modernities. Such a scenario is, however, implausible under current capitalist international trade regimes and 'free-trade' governance structures. It is indeed easier to imagine the end of the world than to imagine the end of capitalism. But we must imagine the end of and alternatives to capitalism. The periphery, the oppressed, has little choice. In fact, Freire (1970) argues that it is the humanistic and historical task of the oppressed to liberate not only themselves but also the oppressor.

> "The oppressors, who oppress, exploit, and rape by virtue of their power, cannot find in this power the strength to liberate either the oppressed or themselves. *Only power that springs from the weakness of the oppressed will be sufficiently strong to free both*. Any attempt to "soften" the power of the oppressor in deference to the weakness of the oppressed almost always manifests itself in the form of *false generosity*; indeed, the attempt never goes beyond this. In order to have the continued opportunity to express their "generosity," the oppressors must perpetuate injustice as well. An unjust social order is the permanent fount of this "generosity," which is nourished by death, despair, and poverty. *That is why the dispensers of false generosity become desperate at the slightest threat to its source*" (Freire 1970:44, emphasis mine).

There is of course a third option: business as usual, to depend on the false generosity or humanitarianism of the oppressive and exploitative system. We can see the false generosity in development aid and the many conventional discourses and policies which shy away from calling for any structural changes but rather suggest that the problems can be solved within existing institutional arrangements. The dispensers of the false generosity - those who benefit from the flawed system - often invoke fear-mongering tactics whenever they hear phrases like "away with capitalism" or "de-link from the global system of exchange."[28] To them, 'autarky' means a total ban, a moratorium on international trade, a disaster to livelihoods for people in the Global South. My dictionary tells me otherwise: autarky means self-sufficiency, living within ecological limits (at local, regional, and global scales). They imagine 'de-linking' to be a newsflash proclaiming that "the Kenyan Government has announced a ban on all exports of coffee starting next week." I envision delinking as much more subtle. Small-scale Kenyan coffee farmers realize that the token money they receive for their coffee is not enough for them to live a decent life and decide to uproot their coffee bushes and instead practice mixed farming, growing food crops and keeping a few cattle for household food security and, when they have surplus, sell to their neighbors or at the local market.

New non-capitalist "modernities" based on cooperative communing that are sustainable yet de-linked from global networks can be built. Many such examples and other grassroots proposals exist. D'Alisa et al. (2015) identify five features shared by such grassroots movements: a shift from production for exchange to that for use, substituting wage labor for voluntary activity, circulation of goods through 'gifting' rather than profits, no built-in accumulation imperative, and based on commoning. They add that growth-less welfare institutions such as job guarantee systems and work sharing, as well as reforming money and credit institutions through community currencies could be pursued. A critical aspect that would have to be thought through is the nature and role of the state in such a 'post-capitalist' society. Some believe that such building of something new can be done on a global scale if we work together. Challenging as it is, that is the beauty of imagination, of social imaginary. It is what inspires those who believe that "Another world is possible", an imaginary different from the Western one based only on the market, the self, and the public sphere (Taylor 2004). EUE theory makes a significant contribution to that process.

[28] The South Centre (2006:13) notes that many developing countries are increasingly realizing that they can use their large numbers and share of global resources to shape their own futures and "delink their development strategies from discredited neo-liberal economic theories and embark on strategies that are more attuned to their specific country circumstances." This informs the recommendation for more South-South cooperation to ensure that "the North-South divide is bridged on the basis of equality rather than of post-colonial and neo-colonial dependency."

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Methodological and Ideological Options

The unequal exchange of Dutch cheese and Kenyan roses: Introducing and testing an LCA-based methodology for estimating ecologically unequal exchange

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ABSTRACT

The theory of ecologically unequal exchange (EUE) posits that international trade is structurally organized in a manner that allows a net transfer of resources from peripheral developing to core industrialized countries. The consequence, it is argued, is under-development in the periphery and augmented productive capacity in the core. EUE thus challenges the neoliberal free-market argument that exchange at market prices is symmetric and fair. An LCA-based methodology for estimating EUE that holds constant the variable market price is introduced and tested on contemporary trade of Dutch cheese and Kenyan coffee and roses. Specifically, the exchange of embodied land, water, energy, global warming potential, and labor is assessed. The results confirm the theory's hypothesis. At a fixed market price, more embodied Kenyan resources are exchanged for less Dutch resources. However, Kenyan roses give different results from coffee. EUE between countries can only be conclusively determined by considering the total biophysical trade balance, but by calculating quantities of embodied resources per unit of exchange value, it is possible to detect unequal exchange even at the level of individual commodities. While integration of biophysical metrics alongside monetary valuation is recommended, ultimately, rethinking the structure, policies and politics of international trade is necessary.

1. Introduction

International trade is structurally organized in such a way that some countries act as natural resource depots and sinks for the waste products of other countries. Materials and energy extracted from peripheral countries predominantly located in the Global South are being used to feed industrial processes and capital accumulation in core Northern countries. The consequence is environmental degradation, poverty, and general underdevelopment in the peripheral countries and improved productive capacity in the developed world (Rice, 2009). This exploitative international division of labor is the essence of the theory of ecologically unequal exchange (EUE). It is concerned with the unequal environmental and human well-being consequences of international trade and the relations of power that generate and maintain such inequality (Hornborg, 2009; Jorgenson et al., 2009). Rather than take present comparative advantages as a given, EUE theory questions the historical power relations that have shaped them and, in so doing, departs from neoclassical economic thought. By considering global terms of trade as favoring core countries to the detriment of the periphery (Jorgenson et al., 2009), the perspective takes a 'zero-sum' view of development (Hornborg, 2011) akin to David Harvey's (2003) 'accumulation by dispossession.'

Rooted in classical trade dependence, unequal exchange, and world-systems traditions (Jorgenson et al., 2009), EUE traces a direct genealogy to Karl Marx's 'metabolic rift' (Hornborg, 2009). The growing asymmetric exchange of nutrients and other material resources between town and countryside in 19th-century Europe amplified by long-distance trade deeply concerned Marx (Foster, 1999). Credited with coining the term unequal exchange, Arghiri Emmanuel (1972), through the labor theory of value, argued that developing countries always exchange a larger amount of their labor for less foreign labor. But it is Raul Prebisch who is credited with founding the theory of unequal exchange (Kohler and Tausch, 2002; Love, 1980). Refuting David Ricardo's theory of comparative advantage, Prebisch observed a hierarchy in the global economic system and deteriorating terms of trade for developing countries which he attributed to low income-elasticity of demand for primary products and asymmetries in the functioning of labor markets (UN., 1963). EUE has also benefited greatly from world-systems analysis (see Frank, 2008; Wallerstein, 1974). World-systems analysis sees an economic and geographical division of the capitalist world-economy into a strong core (metropolis) and weak periphery (satellite) in which surplus value flows from the periphery to the core, a process which limits the periphery's developmental potential. Through his research on the Amazon, Stephen Bunker inserted 'ecology' to earlier labor- and energy-based theories of unequal exchange and, in a sense, assembled the first formulation of a concept of ecologically unequal exchange (Hornborg,

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2009). He argued that (i) differences in the economies of peripheral and core countries create unequal exchange in terms of labor embodied in products *and* the appropriation of energy and matter from the periphery to the core, and (ii) the extraction and export of natural resources affect the subsequent developmental potential of the periphery (Bunker, 1985).

Ecologically unequal exchange rejects neoliberal economics' assumption that market prices are fair or tantamount to reciprocity. Free market transactions are by definition equal and fair since the actors voluntarily exchange currency or goods for what they assess to be of equal value (Clark and Tsai, 2009; Hornborg, 2009). This win–win positive-sum game is a liberal understanding of capitalism encapsulated in David Ricardo's theory of comparative advantage. But the free market functions as an ideology, a myth (Wallerstein, 2004). The equal exchange in monetary terms may very well be consistent with unequal exchange in physical terms. Monetary valuation excludes other possible measures of exchange through which it can be shown that free trade is indeed unequal (Hornborg, 2009). Georgescu-Roegen (1971) illuminated the inverse relationship in which raw materials are of low economic value while manufactures which have dissipated much of their productive potential have a high monetary value. That is why Hornborg (2011; 2009) argues for analytically separating human valuation and physical properties in order to reveal the inequality inherent in capitalist processes. Contrary to comparative advantage claims, free trade does not make all nations equally competitive but rather exposes the weak to the strong who, inevitably, devour the weak (Shaikh, 2007). Such 'free trade' policies are used to open up and integrate peripheral countries into relations of unequal exchange (Bieler and Morton, 2014).

The EUE theory is backed by a growing number of empirical studies using different approaches and methods (see Section 2). Most of these methods and studies take an economy-wide approach that tracks total flows rather than a product-specific perspective. Apart from showing the net flow of biophysical resources, most are also geared towards revealing the environmental or socio-economic impacts of such unequal exchange. What they fail to illustrate is the mechanism(s) through which EUE occurs. Reiterating that the core element of any EUE theory is the exchange of more ecological wealth for less, Foster and Holleman (2014) argue that existing EUE approaches rely on data whose quantitative measures are in monetary prices and which reveal little about the ecological nature of the exchange, i.e. in terms of embodied energy or other resources. As a result, "we learn little or nothing […] about the *processes involved* or the real extent of the unequal exchange" (ibid. pg. 210, emphasis added). This paper introduces a life cycle analysis (LCA)-based methodology for quantifying EUE that simultaneously investigates a key mechanism through which unequal exchange occurs — the free market ideology. The methodology is tested in the contemporary exchange of specific flagship export products from supposedly core (Netherlands) and peripheral (Kenya) countries. The modern nation state remains a crucial instrument by which industrial centers subordinate and attempt to control extractive peripheries, while systematic consideration of specific export commodities has many benefits (cf. Bunker, 1985; Hardt and Negri, 2000). Organizationally, the Introduction discusses the EUE theory, including its critique of free-market trade. Next is a review of some approaches to estimating EUE followed by the Methodology. Finally, the results are presented, discussed, and conclusions drawn.

2. Common Approaches to Estimating Ecologically Unequal Exchange

How societies organize their exchange of material and energy with the natural environment is termed social metabolism (Fischer-Kowalski and Haberl, 1997). Trade is an important socio-metabolic mechanism. While in conventional international monetary trade exports are 'good' and imports 'bad', the reverse is true for trade in physical terms: exports are a loss to the exporting country of the resources embodied in the exports and vice versa. Haberl et al. (2013) distinguish two approaches to analyzing social metabolism. Systemic approaches aims at a comprehensive account of all biophysical flows needed to build up, sustain and operate a defined socioeconomic system. The LCA approach, on the other hand, accounts for resource requirements, wastes and emissions resulting from a single product. As the following review reveals, most methods of quantifying EUE predominantly apply the systemic approach even if some (e.g. footprints and input–output analysis) incorporate elements of LCA.

Material flow analysis (MFA) is one approach to estimating EUE. Based on the mass balance principle from Lavoisier's law of conservation of mass, it accounts for biophysical flows in mass, usually metric tons (Bringezu and Moriguchi, 2002). Physical trade balance (PTB), an MFA-based indicator which measures an economy's physical trade surplus or deficit, can give insight into EUE. Mass is a robust measure in classical physics and PTB gives information on world resource supply and demand, inter-country group resource flows, and resource dependencies (Fischer-Kowalski et al., 2011). Using MFA, Pérez-Rincón (2006) has shown that between 1970 and 2002, 85% of Colombia's export was directed at satisfying the material and energy requirements of Northern countries, in particular the EU and USA. Several other studies (e.g. Behrens et al., 2007; Bruckner et al., 2012; Dittrich and Bringezu, 2010; Schaffartzik et al., 2014) apply MFA to arrive at similar proof of EUE. One drawback of MFA is that weighting of trade does not tell us the ecological impacts of the goods.

Another method, the human appropriation of net primary production (HANPP), estimates the sum of changes in net primary production (NPP) or biomass resulting from land-use change and human harvest from ecosystems, including losses thereof (Haberl, 1997; Haberl et al., 2012). Measured in units of carbon, HANPP is calculated by estimating a country's potential NPP (without human land use) using vegetation models, then calculating the actual NPP (often less than potential NPP), and finally determining the actual part of the NPP utilized by human beings. Embodied HANPP (eHANPP) involves adding the HANPP related to imports and subtracting that related to exports, hence can be used to estimate EUE. Krausmann et al.'s (2013) analysis of HANPP trends shows that Asia, Africa, and Latin America's high HANPP growth rates are due to their importation and consumption by industrialized countries.

Footprints take a consumer responsibility approach to provide a simple but graphic measure of the environmental impact of human activity (Hammond, 2006; Steen-Olsen et al., 2012). The 'footprint family' (Galli et al., 2012) refer to the ecological, carbon and water footprints. The ecological footprint (EF), measured in global hectares (gha), calculates human demand on the biosphere compared to the planet's 'supply' (Wackernagel and Kitzes, 2008). A popularization of Borgstrom's 'ghost acreages', it builds on the concepts of LCA, bio-productivity accounting, and embodied energy analysis (Moran et al., 2009). The water footprint (WF) or 'virtual water' is the total volume of freshwater used to produce a good or consumed by a community (Hoekstra, 2009a; Hoekstra et al., 2009; Mekonnen and Hoekstra, 2011). Expressed in volume per unit of product (m^3/t), the WF is a combination of the blue, green and gray water footprints. The carbon footprint is the total amount of carbon (or CO_2 equivalent) emissions caused by or accumulated over the life of a product or activity, or the sum of a country's emissions related to its consumption, including imports but excluding exports (Galli et al., 2012). It is expressed in kilograms or tons of CO_2 with no conversion to area. Primarily a measure of the appropriation of global sink capacity, the carbon footprint can also gauge EUE. For example, Steinberger et al. (2012) have shown that socio-economic benefits are accruing to carbon-importing rather than carbon-exporting countries. Steen-Olsen et al. (2012) have shown that the EU-27 displaces all the three footprints to the rest of the world through trade.

Input–output (I–O) analysis describes an economic sector's output and its relationship to the corresponding levels of activities in other sectors. Initially applied to economic impact analyses through monetary I–O tables (MIOTs), they have been extended to pollution and other

environmental "externalities" (Leontief, 1970; Allan et al., 2007). A physical I–O table (PIOT) comprises the traditional I–O table in physical units and material flows between the environment and economy (Giljum and Hubacek, 2004; Strassert, 2002). Because an I–O approach can track the transformation and impact of goods through an economy, if extended to multiple regions, the spatial distribution and growth or decline over time of output and consumption of goods can be explained (Moran et al., 2009). It is often used in combination with other methods, e.g. Steen-Olsen et al.'s (2012) use of a multiregional input–output (MRIO) model to assess the displacement of carbon, land and water footprints through trade within and without the EU-27.

Energy metrics such as eMergy (energy memory) have also been used to estimate EUE. Alfred Lotka's postulation that 'natural selection' favors those populations that convert the greater amount of energy has found support from a trade perspective whereby countries or regions that import more embodied energy than they export have a relative economic advantage (Bunker, 1985; Lonergan, 1988). Rydberg (2011) confirms that developed countries' wealth is largely based on imported eMergy.

Life cycle analysis (LCA) is a technique for systematically assessing the environmental aspects and potential impacts associated with a product by compiling an inventory of relevant inputs and outputs; evaluating the potential environmental impacts associated with those inputs and outputs; and interpreting the results of the inventory and impact phases in relation to the objectives of the study (ISO 14040, 2006). It considers the embodied resources and emissions throughout the entire life cycle of a product, i.e. from 'cradle-to-grave.' Going beyond the mass balance principle of MFA, LCA is often used to identify ecological 'hotspots', elements with a high contribution to a product's ecological impact (De Haes, 2002; Van Middelaar et al., 2011). By providing a holistic and systematic overview of embodied resources and emissions, it is routinely used to compare the potential environmental impact of two or more products (Thrane and Schmidt, 2007). Economic and social aspects have also been integrated into LCA (cf. Franze and Ciroth, 2011; UNEP, 2009; Weidema, 2006).

Some challenges such as assuming a functional unit for products with many potential uses and the risk of double counting bedevil LCA (cf. Ayres, 2004; Ayres, 1995; Van der Voet et al., 2005). Nevertheless, it remains the tool of choice for many modern sustainable consumption and production policies. It is often combined with other tools for more extensive assessments (cf. Rochat et al., 2013; Schmidt, 2014; Weinzettel and Kovanda, 2009). Van der Voet et al. (2005) combine aspects of MFA (quantitative information) and LCA (environmental impacts) to assess the environmental impacts of the annual throughput of a number of materials for The Netherlands. Haberl et al. (2013) allude to the future possibility of applying LCA to studies in society–nature interactions across space and time. Until now, LCA has not been used to estimate ecologically unequal exchange.

3. Methodology

The proposed methodology has two key parts. First, the embodied resources and impacts per unit of product are determined using LCA. However, what we have not yet brought into the picture are the structural aspects of international trade, so-called 'market forces'. The second part of the methodology is dedicated to this. By combining the resource embodiment of each product (from step 1) with exchange rates deduced from the world market, the resource intensity per unit of exchange value (e.g. US Dollar) is determined and compared across the products. In this way, we can illuminate the 'free market' mechanism through which asymmetric resource flows occurs.

3.1. Embodied Resources per Unit of Product

ISO 14040 (2006) and ISO 14044 (2006) are internationally accepted standards which describe the principles, framework, requirements, and guidelines for life cycle assessment. These have been used to establish embodied resources and emissions per unit of product. The LCA framework is comprised of four iterative phases: goal and scope definition, inventory analysis (LCI), impact assessment (LCIA), and interpretation of results (ISO 14040, 2006). The goal of this study is to quantify the biophysical resource and emission embodiments of the target products with a view to establishing the occurrence of unequal exchange. The scope involves defining the functional unit, system boundary and co-product allocation criteria. A functional unit (FU) is a quantified output of a production system which allows different such systems to be compared (Thrane and Schmidt, 2007). The FUs were defined as follows: 1 kg of long-stemmed, plastic greenhouse-grown, graded and packaged Kenyan rose flowers; 1 kg of milled and packaged green Kenyan coffee beans (not roasted); and 1 kg of Dutch Gouda cheese produced from conventional (not organic) milk. Figs. 1, 2 and 3 show the system boundaries of the processes included in the analysis. Since the focus is on bilateral trade, only domestic resources and related emissions were considered, with imported raw materials treated as if they were locally sourced. While this may distort the results especially for Dutch agricultural products due to their relatively high external inputs (De Boer et al., 2013; Thomassen et al., 2008; Van Bruchem et al., 1999; Vellinga et al., 2011), such a distortion implies that there are in fact less truly Dutch resources embodied in a unit of their cheese. Hence, in the context of the present investigation of EUE, the distortion, though important to keep in mind, does not compromise but rather underscore the integrity of the conclusions. Emissions due to use of imported inputs in the production process (e.g. combustion of imported fossil fuels) were attributed to the final product and country of production. Allocation of inputs to stages with more than one output (co-product allocation) was based on their relative economic value (i.e. economic allocation).

Infrastructure and capital goods such as roads, buildings, and machinery were omitted due to their relatively small impact per functional

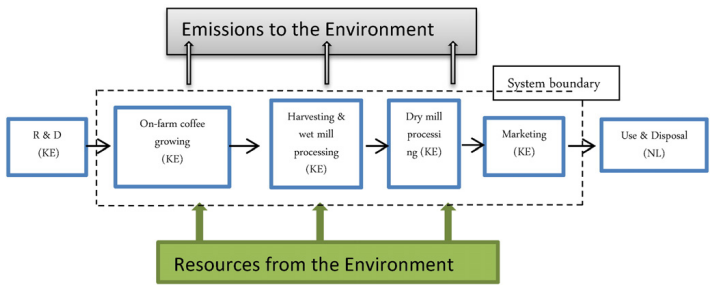

Fig. 1. System boundary for Kenyan coffee.

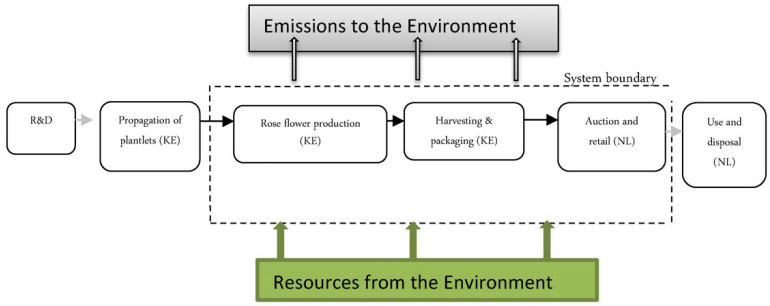

Fig. 2. System boundary for Kenyan roses.

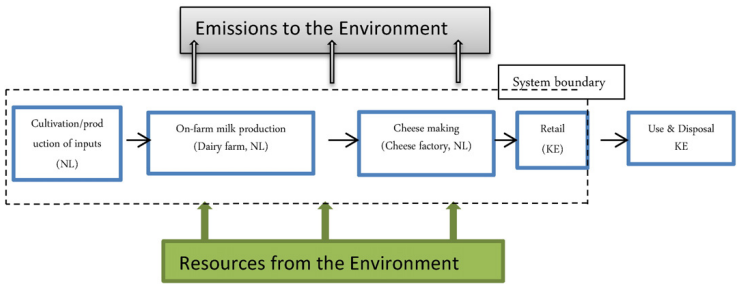

Fig. 3. System boundary for Dutch cheese.

unit, the norm in many LCA studies (cf. Thomassen et al., 2009, 2008; Van Middelaar et al., 2011). While the ISO standards suggest treatment of capital goods as integral parts of a product system, the justification for such omission hinges on the fact that due to their often long lifespans and the many different products and socio-economic activities utilizing the same infrastructure, the resources and emissions embodied in the capital goods attributable to a unit (1 kg) of a particular product is not only difficult to estimate but would, if done, turn out to be negligible. Cumulatively, infrastructure has significant ecological impacts, a point often better captured by the systemic EUE approaches. Processes similar across the products (e.g. inter-continental air freight) were disregarded on the assumption that, assuming similar technology, transporting a unit (1 kg) of coffee or cheese between the two countries should expend or emit roughly similar amount of resources. Land use, water, energy, CO_2 emissions or global warming potential (GWP), and labor were the focal resource and impact categories, i.e. the environmental components and issues of concern.

The inventory phase (LCI) involves collecting and quantifying the inputs and outputs of production processes included in the system boundary and relating the data to the functional unit, i.e. determining resource intensity per functional unit (ISO 14040, 2006; Thrane and Schmidt, 2007). Data on Kenyan roses was collected from Nini Flower farm located in Naivasha between October and December 2012. That of coffee was collected from Mchana estate, a coffee plantation located in Ruiru District, central Kenya between December 2013 and January 2014. Farm records, observation, and direct measurements were relied upon and triangulated with other secondary data sources and literature to verify their accuracy. No LCA database or software was used as none specific to Kenya currently exists. Data on Dutch cheese was sourced from literature. Tables 1, 3 and 5 summarize each product's inventory. The third phase (impact assessment) uses the LCI data to evaluate the significance of the resource requirements and environmental impacts of a production system. The result is total embodied resources and impacts per functional unit (the last row of the

Table 1
Life-cycle inventory table of Kenyan rose flower production.

Process/input	Land use	Energy	GWP	Water	Labor
1. Greenhouse	0.5 ha (1.5×10^{-5} ha/kg)	–	–	–	
2. Rose production:					
–Water consumption	1.267 ha (8.45E-7 ha/kg)	–	–	360 l/kg	
–Synthetic fertilizer	–	–	0.017 kg CO_2eq/kg		
3. Packaging:					
–Cardboard	1.2×10^{-6} ha/kg	9 MJ/kg	–	–	
–Plastics	–	3.32 MJ/kg	0.0776 kg CO_2/kg	–	
4. Transportation	–	2 MJ/kg	0.152 kg CO_2/kg	–	
5. Electricity	–	2.6 MJ/kg	0.19 kg CO_2/kg	–	
TOTAL	1.7045×10^{-5} ha/kg	16.92 MJ/kg	0.4346 kg CO_{2eq}/kg	360 l/kg	0.86 h/kg

Table 2
Trade volumes and embodied resources.

Year	Kenyan rose exports to The Netherlands		Embodied resources				
	Export (Mt)	Inflation adj. sales (US$)	Land use (ha)	Water (l)	Energy (MJ)	GWP (Kg CO_2eq)	Labor (h)
1995	9257.43	19,611,423.24	157.79	3,332,674,800	156,635,715.6	4,023,279.08	7,961,389.8
1996	9834.37	18,486,187.89	167.63	3,540,372,732	166,397,518.4	4,274,016.64	8,457,557.09
1997	11,871.15	23,557,977.48	202.34	4,273,613,370	200,859,828.4	5,159,201.03	10,209,187.5
1998	12,659.90	31,560,545.99	215.79	4,557,564,180	214,205,516.5	5,501,992.76	10,887,514.43
1999	16,017.47	41,749,599.32	273.02	5,766,287,436	271,015,509.5	6,961,190.33	13,775,019.99
2000	18,023.75	39,613,177.08	307.21	6,488,550,432	304,961,870.3	7,833,122.27	15,500,426.03
2001	19,664.44	58,440,251.81	335.18	7,079,198,958	332,722,351	8,546,166.30	16,911,419.73
2003	29,684.57	63,722,172.38	505.97	10,686,443,742	502,262,855.9	12,900,912.36	25,528,726.72
2004	31,407	77,108,800.71	535.33	11,306,521,044	531,406,489.1	13,649,483.46	27,010,022.49
2005	39,684.1	86,607,806.79	676.42	14,286,275,640	671,454,955.1	17,246,709.43	34,128,325.14
2006	41,221.74	94,059,747.61	702.62	14,839,825,104	697,471,779.9	17,914,966.64	35,450,693.3
2007	43,100.06	139,763,305.6	734.64	15,516,022,392	729,253,052.4	18,731,287.03	37,066,053.49
2008	35,182.20	182,338,645	599.68	12,665,592,000	595,282,824	15,290,184	30,256,692
2009	30,588.33	167,193,690	521.38	11,011,798,800	517,554,543.6	13,293,688	26,305,964
2010	32,377.83	164,656,369	551.88	11,656,018,800	547,832,883.6	14,071,405	27,844,934
2011	60,698.21	175,473,795	1034.60	21,851,355,600	1,027,013,713	26,379,442	52,200,461
2012	58,500.01	157,954,455	997.13	21,060,003,600	989,820,169.2	25,424,104	50,310,009

Source: Trade data sourced from COMTRADE (2014) and HCDA (Horticultural Crops Development Authority) (2014). Embodied resources calculated by author.

Table 3
Life-cycle inventory table of Kenyan coffee.

Process/input	Land use	Energy	GWP	Water	Labor
1. Coffee production	908.9 ha (2.23 ha/t)	–	–	23,573 m^3/t	113.774 h/kg
2. Fertilizer application	–	–	0.94 t CO_2eq/t	–	–
3. Fuel consumption	–	31, 435 MJ/t	2.28 t CO_2eq/t	–	–
4. Electricity consumption	–	3440 MJ/t	0.3 t CO_2eq/t	–	–
TOTAL	2.23×10^{-3} ha/kg	34.875 MJ/kg	3.52×10^{-3} t CO_2eq/kg	23.573 m^3/kg	113.774 h/kg

inventory tables). However, the calculation of resource intensity per functional unit is only the first stage in the methodology. The next stage relates these calculated figures to exchange value to determine unequal exchange per dollar.

3.2. Determination of Unequal Exchange

Determination of unequal exchange per dollar helps us investigate the reciprocity claims of free trade and comparative advantage theories from a biophysical perspective. Doing so requires information about the exchange rates obtaining in the world market. The exchange rates were deduced from annual import and export trade statistics retrieved, in both weight and monetary sale values, from the UNCOMTRADE database. The COMTRADE codes of interest were 060,311 (fresh roses), 090,111 (coffee, not roasted, not decaffeinated) and 0406 (cheese and curd). Kenyan rose exports to The Netherlands from 1995 to 2007 were missing from COMTRADE and were instead sourced from Kenya's Horticultural Crops Development Authority (HCDA (Horticultural Crops Development Authority), 2014) by assuming 65% of all Kenyan rose exports go to The Netherlands (cf. Dolan et al., 2003; Kargbo et al., 2010; KFC (Kenya Flower Council), 2014; Rikken, 2011). Based on life cycle assessments of the respective trade goods (from Step 1), how much of a particular resource (e.g. embodied land) was traded on the world market at a fixed exchange value (e.g. US$1) in a given year is determined. Then a comparison (visualized in the form of a graph) is made between how much of each resource embodied in a Kenyan product was exchanging for a similar resource embodied in Dutch cheese at a fixed exchange value (arbitrarily set at US$10,000 in this paper). But first, the monetary prices were adjusted for inflation using the respective countries' consumer price index (CPI). The CPI figures for Kenya and The

Table 4
Trade volumes and embodied resources.

Year	Kenyan coffee export to The Netherlands		Embodied resources				
	Export (kg)	Inflation adj. sales (US$)	Land use (ha)	Water (l)	Energy (MJ)	GWP (kg CO_2eq)	Labor (h)
1995	4,848,414	16,995,446	10,812	1.1429E + 11	1,690,884,38.3	17,066,417.28	551,623,454.4
1996	6,280,511	15,871,298	14,006	1.4805E + 11	219,032,821.1	22,107,398.72	714,558,858.5
1997	2,533,000	6,697,142	5649	5.971E + 10	88,338,375	8,916,160	288,189,542
1998	1,420,250	2,836,781	3167	3.348E + 10	49,531,218.75	4,999,280	161,587,523.5
2000	10,624,371	14,983,643	23,692	2.5045E + 11	370,524,938.6	37,397,785.92	1,208,777,186
2001	6,511,145	7,923,508	14,520	1.5349E + 11	227,076,181.9	22,919,230.4	740,799,011.2
2002	1,298,142	1,558,224	2895	3.0601E + 10	45,272,702.25	4,569,459.84	147,694,807.9
2004	4,137,129	5,063,479	9226	9.7525E + 10	144,282,373.9	14,562,694.08	470,697,714.8
2005	3,933,267	7,079,750	8771	9.2719E + 10	137,172,686.6	13,845,099.84	447,503,519.7
2007	3,286,199	6,214,796	7328	7.7466E + 10	114,606,190.1	11,567,420.48	373,884,005
2008	597,691	1,374,477	1333	1.4089E + 10	20,844,473.63	2,103,872.32	68,001,695.83
2009	615,105	1,198,491	1372	1.45E + 10	21,451,786.88	2,165,169.6	69,982,956.27
2010	443,046	1,062,602	988	1.0444E + 10	15,451,229.25	1,559,521.92	50,407,115.6
2011	697,387	2,503,568	1555	1.644E + 10	24,321,371.63	2,454,802.24	79,344,508.54
2012	1,040,826	2,793,308	2321	2.4535E + 10	36,298,806.75	3,663,707.52	118,418,937.3

Source: Trade data sourced from COMTRADE (2014). Embodied resources calculated by author.

Netherlands were sourced from the Kenya National Bureau of Statistics (KNBS (Kenya National Bureau of Statistics), 2014) and the International Monetary Fund (ECONSTATS, 2013) respectively.

3.3. Case Study Countries and Products

From a world-systems perspective, Kenya is peripheral and The Netherlands a core country. Ranked as a low-income economy by the World Bank, Kenya exports mainly 'low-value' agricultural products such as tea, coffee and horticultural crops to Europe and the US and imports 'high-value' industrial manufactures such as machinery and other capital equipments, fuel and other non-food industrial supplies from the Middle and Far East. Manufactures' contribution to GDP has stagnated at about 10% for decades. Kenya has become a net importer in recent years with deteriorating terms of trade. The Netherlands is Kenya's third largest export market, accounting for between 8 and 9% of all exports, mainly cut-flowers (Bridgat, 2013; KIPPRA, 2013; KoN (Kingdom of Netherlands), 2014; UNStats, Undated). The industrialization and 'core' attributes of The Netherlands was already present as far back as the fifteenth century (Van Bavel and Van Zanden, 2004). It exports about 1.48% worth of its goods to Kenya, mainly chemicals, machinery and dairy products, making Kenya the fifteenth largest export destination for Dutch products (Bridgat, 2013; KoN (Kingdom of Netherlands), 2014).

Coffee is exclusively a tropical and labor-intensive crop grown by less-developed countries but largely consumed in the developed world (Austin, 2012). Cut flowers are an important export-directed world trade commodity, are both capital- and labor-intensive, and have significant environmental and socio-economic impacts (cf. Kargbo et al., 2010). Cheese is a traded product from the dairy industry which embodies significant environmental resources and emissions (cf. Steinfeld et al., 2006). Green coffee beans and fresh cut flowers are primary products while cheese is processed from milk, and thus a manufacture of sorts. In addition to their socio-economic value, these characteristics make them good candidates for estimating EUE. However, any other product can be chosen to test the proposed methodology for assessing the veracity of EUE theory.

World floriculture production was valued at US$40 billion in 2009 (Kargbo et al., 2010). Considered an economic success story, horticulture accounts for about 26.7% value of all Kenyan exports (Leipold and Morgante, 2013; UNStats, Undated). Produced almost exclusively for export, cut flower is the most important sub-sector of the Kenyan horticultural industry, accounting for about 57% of the total horticulture exports (ITC (International Trade Centre), 2004). Over 65% of the flower exports go to The Netherlands (Dolan et al., 2003; Kargbo et al., 2010; KFC (Kenya Flower Council), 2014; Rikken, 2011). The area around Lake Naivasha, an internationally important Ramsar wetland, account for about 95% of all flower production (Becht et al., 2006; Kargbo et al., 2010). Roses (*Rosa* sp.) account for over 50% of all cultivated flowers and 70% of all exports (Kargbo et al., 2010; KFC (Kenya Flower Council), 2014; Mekonnen et al., 2012). Kenya supplied 63% of all EU rose imports in 2006 (Muhammad, 2009). Rose production is both capital and labor intensive, requiring temperatures of between 15 and 28 °C, constant humidity, and a minimum 10 h of daily sunlight (Franze and Ciroth, 2011), conditions achieved in Kenya by growing them in plastic greenhouses (HCDA (Horticultural Crops Development Authority), 2014). Over 90% of Kenya's annual coffee production is exported, contributing about 4% of total export earnings. Largely grown by small-scale farmers, the superior quality but low yielding Arabica coffee (*Coffea arabica*) is the main variety (CRF (Coffee Research Foundation), 2014; ICO (International Coffee Organization), 2014).

The Dutch dairy industry utilizes 44% of the country's land and accounts for about 17% of the value of its food exports (CBS (Netherlands Central Bureau of Statistics), 2012). About 98% of Dutch milk is conventional, i.e. not organic (Thomassen et al., 2008). Over half of all milk supplied to dairy factories is processed into cheese, 75% of which is exported (CBS (Netherlands Central Bureau of Statistics), 2012; CBS (Netherlands Central Bureau of Statistics), 2005; Van Middelaar et al., 2011). Gouda is the dominant cheese (Van Middelaar et al., 2011; Walstra et al., 1999). Dutch agriculture is intensive in capital and external nutrient input (Van Bruchem et al., 1999; Vellinga et al., 2011).

4. Results

4.1. Embodied Resources in Kenyan Rose Flowers

Nini Flower farm's productivity is 65.172 t/ha. This approximates Orr and Chapagain's (2006) reported yield of 66 t/ha for Kenyan roses. About 23 ha are under rose flower cultivation and 1.267 ha is appropriated annually for lake water collection, treatment and disposal. Due to lack of comprehensive water use records, Mekonnen et al.'s (2012) reported water footprint of rose flowers grown around L. Naivasha of 9 l per stem (or 360 l/kg) was used.

Kenya does not produce any artificial fertilizers, hence only nitrous oxide (N_2O) emissions related to synthetic nitrogen fertilizer application (Kramer et al., 1999; Rotz et al., 2010) were considered. The emissions are 0.017 kg CO_2eq/kg of roses.[1] One export box contains about 250 rose stems weighing 6.25 kg, and packaging material made up of 1.91 kg cardboard and 0.25 kg plastic. The cardboard embodies a land use of 1.2×10^{-6} ha/kg[2] and energy of 9 MJ/kg of roses,[3] while the plastic packaging embodies 3.32 MJ/kg[4] and 0.0776 kg CO_2/kg of roses.[5] The annual fuel consumption (452.6 l petrol and 83,829 l diesel) embodies 2 MJ/kg[6] and emits 0.15 kgCO_2/kg of rose.[7] Electricity consumption embodies 2.6 MJ/kg[8] and emits 0.19 kgCO_2/kg.[9] With 538 employees and

[1] Based on Kenya's 2010 CO_2 emissions from synthetic nitrogen fertilizer use of 457 GgCO_2eq (FAOSTAT, 2013) and total fertilizer consumption of 500,000 metric tons (IFDC, 2012) gives an emission rate of 0.9 t CO_2eq/t of fertilizer. The annual Nitrogen (N) fertilizer consumption of 624.61 kg/greenhouse emit 562 kgCO_2eq, translating into 0.017 kg CO_2eq/kg.

[2] 78,000 ha of Kenya's plantations and 10% (100 ha) of farmlands were under wood production in 2000 (Wass, 2000). Kenya produced 135,000 t of packaging paper between 2006 and 2008 (FAO, 2012). Since general industrial roundwood weigh 750 kg/m^3 (FAO, 2012), packaging paper appropriated 180,000 m^3 of the annual roundwood production. Kenya's total wood production in 2010 was 27,646,000 m^3 (FAO, 2012). Assuming acreage (78,100 ha) and wood production (27,646,000 m^3) has remained constant, 135,000 tonnes (or 180,000 m^3) of packaging paper require 508.5 ha to produce. 305.6 kg of packaging paper (to wrap 1 tonne of roses) require 0.0012 ha of land annually to be produced, or 1.2×10^{-6} ha/kg of rose.

[3] Cardboard embody 29.97 MJ/kg (Hammond and Jones, 2008). Since 6.25 kg of flowers require 1.91 kg of cardboard to wrap, 1 kg of flowers will need 0.3 kg of cardboard, or about 9 MJ of energy.

[4] General plastic embody 83 MJ/kg and 1.94 kg CO_2/kg (Hammond and Jones, 2008). The 40 kg of plastics used to wrap 1 t of roses gives an embodied energy of 3320 MJ/t (or 3.32 MJ/kg) of rose flowers.

[5] From d above, emissions from plastics is 77.6 kg CO_2/t (or 0.0776 kg CO_2/kg).

[6] Petrol and diesel have an energy content of 44.3 MJ/kg and 43 MJ/kg respectively (IPCC, 2006). Since 1 kg of petrol is approx. 1.3 l, 452.6 l = 15,546 MJ. On the other hand 1 kg of diesel is approx. equal to 1.2 l, hence 83,829 l = 3,003,873 MJ. The combined total fossil fuel energy use (3,019,419 MJ) and annual rose flower production of the entire farm (1,498,956 kg) gives an energy use rate of 2 MJ/kg.

[7] The CO_2 emission factor of petrol and diesel are 69,300/TJ and 74,100 kg CO_2/TJ respectively (IPCC, 2006). 452.6 l of petrol = 15,546 MJ which emits 1.077 tCO2eq, while 83,829 l of diesel = 3,003,873 MJ which emits 222.587 tCO2eq. The combined emission is 224 tCO_2 per annum, or 0.15 kg CO_2/kg.

[8] Kenya generated 7273 GWhs of electricity less imports in 2010/2011 (GoK, 2012), while its 2010 CO_2 emissions from electricity production was 2.1 million tons (IEA, 2012). 21,551 KWh (annual consumption of a greenhouse) thus emits 6.2 tonnes CO_2, or 0.19 kg CO_2/kg.

[9] Fossil fuels generated 2288 GWhs of electricity out of which 2020 GWhs were from combustion of diesel and 268 GWhs from petrol. Based on electricity generation-related emissions for 2010, this translates to 583,253 tCO_2 and 77,382 tCO_2 emissions linked to diesel and petrol respectively. With CO_2 emission factors of 74,100 kg CO_2/TJ and 69,300 kg CO_2/TJ for diesel and petrol respectively (IPCC, 2006), the CO_2 emissions above come from 7871 TJ of diesel and 1117 TJ of petrol, a total of 8988 TJ. Since 2288 GWhs was produced from 8988 TJ of fossil fuels, it follows that 21,551 kWhs (single greenhouse annual electricity consumption) was generated from 0.085 TJ, which translates to 2.6 MJ/kg of roses.

Stage	Ecological impact		
	GWP (kg CO_2-eq./FU)	Land use (m^2/FU)	Energy use (MJ/FU)
Cultivation of concentrate ingredients	1.03	1.63	15.58
Concentrate production	0.08	0.00	1.04
Other up-stream stages	0.91	1.03	9.68
On-farm milk production	5.50	3.94	5.89
Sum on-farm milk production and up-stream stages	7.5	6.6	32.2
Cheese-making	0.30	0.01	6.01
Storage	0.29	0.01	4.46
Packaging	0.38	0.17	3.38
Retail	0.02	0.00	1.11
Sum stages after farm gate	0.99	0.2	15.0
Total	8.5	6.8	47.2

Fig. 4. LCA of Dutch cheese. Source: Van Middelaar et al. (2011). FU (functional unit) = 1 kg cheese.

Table 5
Summary inventory of Dutch cheese.

Stage/Resource	Land use	Energy	GWP	Water	Labor
Cheese production	6.8×10^{-4} ha/kg	46.09 MJ/kg	8.48 kg CO_2eq/kg	2623 l/kg	0.118 h/kg

considering sickness and absenteeism, annual labor-time is 1,289,790 man-hours or 0.86 h/kg of rose. Tables 1 and 2 shows the LCA inventory and embodied resources in Kenyan roses respectively.

4.2. Embodied Resources in Kenyan Coffee

The case study Mchana coffee estate occupies 906.91 ha while the dry mill stands on 2 ha, a total land use of 908.91 ha. The average annual yield is 407 t of milled green coffee beans, giving a land use rate of 2.23 ha/t. Mekonnen and Hoekstra's (2011) reported Kenyan coffee water footprint of 23,573 m^3/t (green: 22,222, blue: 802, gray: 549) was used. The wet mill utilizes only 0.34% of the water used to grow the coffee plant (Chapagain and Hoekstra, 2007). Fertilizer application emits 0.94 t CO_2eq/t.[10] Annual fuel consumption (diesel: 83,405 l and kerosene: 279,844 l) embodies 12,794,225 MJ of energy or 31,435 MJ/t[11] and emits 926,480 kg CO_2eq or 2276 kg CO_2eq/t.[12] Annual electricity consumption (357,622 kWh) emits 103 t CO_2eq or 0.3 t CO_2eq/t[13] and embodies 1.4 TJ or 3440 MJ/t.[14] The GWP would be lower if CO_2 removals by coffee plants was considered. The 18,552 employees supply 46,305,792 man-hours annually, translating into 113.774 h/kg of green coffee. Tables 3 and 4 shows the LCA inventory and embodied resources in Kenyan coffee respectively.

[10] About 393,758 kg of synthetic fertilizer is applied in the coffee fields annually. Considering Kenya's 2011 emissions from fertilizer application of 487.53 $GgCO_2$eq (FAOSTAT, 2014) and the country's 2011 fertilizer consumption of 500,000 t (IFDC, 2012), the farm's annual fertilizer consumption emits about 384 t of CO_2eq. This translates to 0.94 t CO_2eq/t.

[11] The energy content of diesel and kerosene is 43 TJ/Gg and 43.8 TJ/Gg respectively (IPCC, 2006). Since 1.2 l of diesel is approx. equal to 1 kg, 83,405 l = 69.5 t, containing 2,988,500 MJ. On the other hand 1 l of kerosene is approx. equal to 0.8 kg, 279,844 l = 223.875 t, containing 9,805,725 MJ. The combined energy use (12,794,225 MJ) and coffee yield (407 t) gives an energy use rate 31,435 MJ/t.

[12] Diesel and kerosene have a CO_2 emission factor of 74,100 and 71,900 kg CO_2eq/TJ respectively (IPCC, 2006). Therefore the above (k) energy contents of diesel (2,988,500 MJ) and kerosene (9,805,725 MJ) emit 221,448 kg CO_2eq and 705,032 kg CO2eq respectively. The combined total is 926,480 kg CO2eq, or 2276 kg CO2eq/t.

[13] Kenya's electricity generation was 7273 GWh less imports in 2010/2011 (GoK, 2012). Its 2010 CO_2 emissions from electricity production were 2.1 million tons (IEA, 2012). Therefore 357,622 kWh emitted 103 t CO_2eq, or 0.3 t CO_2eq/t.

[14] Fossil fuels generated 2288 GWhs of Kenya's electricity in 2010/2011 (GoK, 2012). Out of this, 2020 GWhs were generated by combustion of diesel and 268 GWhs from petrol. Based on the country's electricity generation-related emissions for 2010 (2.1 million tons), this translates to 583,253 tCO_2 and 77,382 tCO_2 respectively. Given the CO_2 emission factors of 74,100 kg CO_2/TJ and 69,300 kg CO_2/TJ for diesel and petrol respectively (IPCC, 2006), the CO_2 emissions come from 7871 TJ of diesel and 1117 TJ of petrol, a total of 8988 TJ. Since 2288 GWhs was produced from 8988 TJ of fossil fuels, it follows that 357,622 kWhs was generated from 1.4 TJ, or 3440 MJ/t of green coffee.

4.3. Embodied Resources in Dutch Cheese

Van Middelaar et al.'s (2011) LCA of Dutch cheese (Fig. 4) was used, minus the retail stage, which was assumed to take place in Kenya. The Dutch cheese study relied on data from Thomassen et al. (2009; 2008), who report purchased concentrate ingredients as originating from within The Netherlands and outside. Generally, a significant part of Dutch livestock feed is imported (cf. De Boer et al., 2013; Van Bruchem et al., 1999). As already indicated under Methodology, the imported ingredients were assumed to be locally sourced, i.e. produced from Dutch domestic resources. Mekonnen and Hoekstra's (2010) reported water footprint for Dutch cheese of 2623 m^3/t (green: 2283, blue: 219, gray: 121) was used. A labor input of 0.118 h/kg of cheese was applied.[15] Tables 5 and 6 show the LCA inventory and embodied resources in Dutch cheese respectively. The first cheese import from The Netherlands to Kenya reported in COMTRADE is in 1995, three years after liberalization of the Kenya dairy industry in 1992 (EPZA (Export Processing Zones Authority), 2005). A sharp rise in imports is seen in 1998 and 2004, and very low figures in 2008 and 2009, giving an overall irregular trend. While this is puzzling, the data for cheese imports from the rest of Europe (EU-27) retrieved from the same COMTRADE database (Table 6) in comparison show a general steady increase over the same period. No explanation for the apparent irregularities could be found, but the data were deemed reliable.

5. Discussion

5.1. Exchange of Kenyan Coffee for Dutch Cheese

More embodied Kenyan resources are consistently exchanged per dollar in the trade of Kenyan coffee for Dutch cheese. This is observed in all the resources considered, namely embodied land, water, energy, and labor. In a hypothesized exchange system in which only these two commodities were under consideration, a net flow of resources to The Netherlands would clearly be realized.

A diagram indicating the quantity of embodied land exchanged per dollar (Fig. 5) shows that Kenya in the trade of coffee for cheese is exchanging more of its embodied land resources for less of Dutch land.

[15] In 2007, the Dutch agricultural sector employed about 165,100 people working full time, with 25% of all the agricultural holdings specialized in dairy farming (Martins, 2008), giving an estimated 41,275 people employed full time. With official working hours of 40 h a week, this translates into 85,852,000 h per year. In the same year (2007), 730,333 t of cheese were produced (CBS, 2014), giving a labor use of 0.118 h/kg cheese.

Table 6
Trade volumes and embodied resources.

Year	Dutch cheese export to Kenya		EU-27 cheese export to Kenya	Embodied resources in Dutch cheese exports to Kenya				
	Export (kg)	Inflation adj. sales (US$)	Export (kg)	Land use (ha)	Water (l)	Energy (MJ)	GWP(kg CO_2eq)	Labor (h)
1995	89	1906	–	0.06052	233,447	4102.01	754.72	10.50
1996	18	1945	–	0.01224	47,214	829.62	152.64	2.12
1997	671	8822	–	0.45628	1,760,033	30,926.39	5690.08	79.18
1998	12,666	65,933	–	8.61288	33,222,918	583,775.94	107,407.68	1494.59
2000	2060	18,450	45,573	1.4008	5,403,380	94,945.4	17,468.8	243.08
2001	1360	11,886	80,264	0.9248	3,567,280	62,682.4	11,532.8	160.48
2002	978	19,321	71,053	0.66504	2,565,294	45,076.02	8293.44	115.40
2004	5253	39,566	65,972	3.57204	13,778,619	242,110.77	44,545.44	619.85
2005	58	1714	50,508	0.03944	152,134	2673.22	491.84	6.84
2007	829	13,688	73,714	0.56372	2,174,467	38,208.61	7029.92	97.82
2008	5	277	98,522	0.0034	13,115	230.45	42.4	0.59
2009	1	99	113,798	0.00068	2623	46.09	8.48	0.12
2010	5856	38,694	113,671	3.98208	15,360,288	269,903.04	49,658.88	691.01
2011	6574	38,067	158,300	4.47032	17,243,602	302,995.66	55,747.52	775.73
2012	3584	22,725	133,965	2.43712	9,400,832	165,186.56	30,392.32	422.91

Source: Trade data sourced from COMTRADE (2014). Embodied resources calculated by author.

The highest inequality of such exchange was in 2002 when US$10,000 was able to buy about 18.58 ha of embodied Kenyan land, while a similar amount of money could only buy 0.34 ha of embodied Dutch land. Virtual water (Fig. 6) follows a similar trend. The exchange of embodied energy per dollar (Fig. 7) also fits the hypothesized ecologically unequal exchange pattern. Through the factor-price equalization theorem, it is claimed that with free trade, the wages and rents earned on capital will progressively equalize across the world (cf. Suranovic, 2010). This is not the case in the exchange of Kenyan coffee and Dutch cheese. There is no discernible convergence in wages since US$10,000 is continuously able to buy more embodied Kenyan labor than Dutch labor (Fig. 8). The generally low wages of coffee workers verifies Emmanuel's (1972) observation that peripheral countries tend to trade many badly paid domestic hours of work for a few hours of well-paid foreign work. Mass is the metric used by MFA. The exchange of mass per dollar yields similar results — more Kenyan mass is exchanged per dollar (Fig. 9).

5.2. Exchange of Kenyan Roses for Dutch Cheese

Analyzing the exchange of Kenyan rose flowers for Dutch cheese presents mixed results. In several instances, the results seem to contradict the EUE hypothesis. The exchange per dollar of embodied land is illustrated in Fig. 10. Here, The Netherlands consistently exchange more of its embodied land resource for less Kenyan land at a fixed market price. In the exchange of virtual water (Fig. 11), no clear pattern of unequal exchange constantly to the detriment of one partner is visible, but Kenya seems to have an advantage, losing out in only five out of the fourteen years under consideration. Energy exchange similarly presents no clear pattern constantly in favor of one trading partner, even

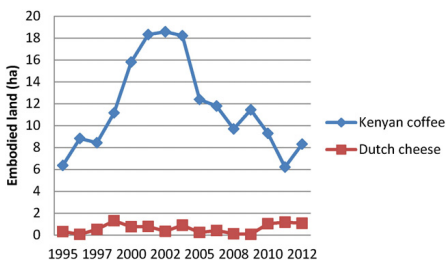

Fig. 5. Exchange of embodied land at fixed (US$10,000) price.

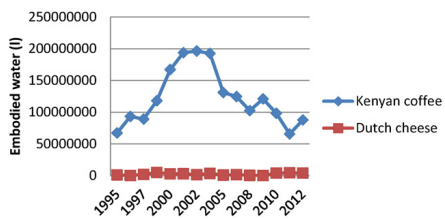

Fig. 6. Exchange of virtual water at fixed (US$10,000) price.

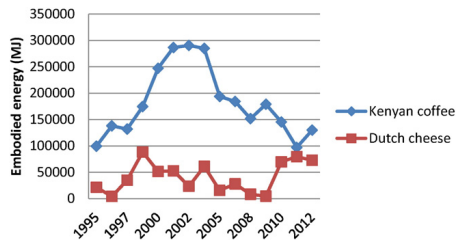

Fig. 7. Exchange of embodied energy at fixed (US$10,000) price.

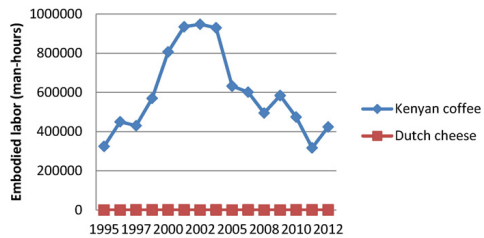

Fig. 8. Exchange of embodied labor at fixed (US$10,000) price.

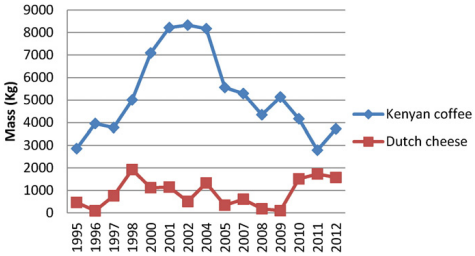

Fig. 9. Exchange of embodied mass at fixed (US$10,000) price.

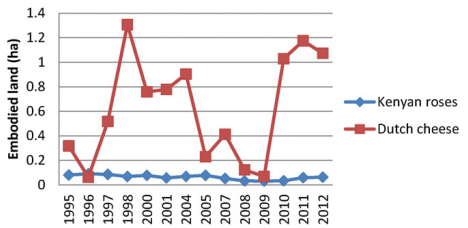

Fig. 10. Exchange of embodied land at fixed (US$10,000) price.

though The Netherlands still has a slight advantage, exchanging less embodied energy per dollar for a combined ten out of the fourteen years considered (Fig. 12).

From a traditional comparative advantage and free market trade perspective, rose flowers would perfectly fit the bill of a product for which Kenya has a 'comparative advantage'. The typical recommendation would thus be for Kenya to continue to invest in and internationally trade in the crop (cf. Hoekstra, 2009b; Mekonnen and Hoekstra, 2011). The export of less water-intensive yet high value roses would thus be a water-saving strategy. Even so, such enthusiasm is tempered by environmental considerations. Cut flower and vegetable farms around Lake Naivasha have been blamed for polluting and reducing the lake's water levels and biodiversity (Becht et al., 2006; Food and Water Watch, 2008; Mekonnen et al., 2012). As Kargbo et al. (2010:7406) puts it, "the tons of flowers flown out of Kenya to Europe go with the lake."

In contrast to the above argument and in line with the EUE theory, we explain the apparently anomalous case of Kenyan rose flowers by its core-like characteristics. Wallerstein (2004) distinguishes core-like and peripheral products based on degree of monopolization, which is directly related to profitability, core-like products being those

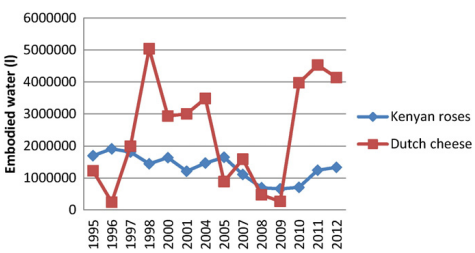

Fig. 11. Exchange of virtual water at fixed (US$10,000) price.

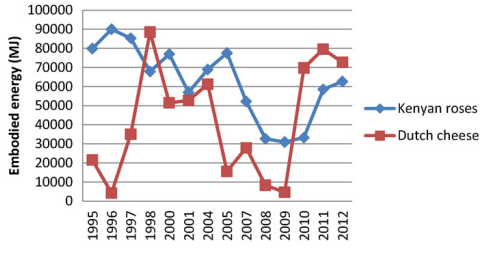

Fig. 12. Exchange of embodied energy at fixed (US$10,000) price.

controlled by quasi-monopolies. Thus, in the exchange process, there is a constant flow of surplus-value from the owners of peripheral products to those of core-like products. Core products are often capital intensive through deployment of technology hence less labor-intense; characterized by a high ratio of capital to market value, spatially aggregated to reduce infrastructure costs and attract a lot of labor which reduces wages, and requires little or no further processing (Bunker, 1985). These conditions, typical of intensive agricultural production in the developed countries, are largely satisfied by Kenyan rose flower production. But technology can serve as a fetish that mystifies relations of unequal exchange (Hornborg, 2011; Hornborg, 2001). Moreover, foreign direct investment (FDI) and international outsourcing of production have been shown to make developing countries more vulnerable to global political–economic conditions and often leads to negative domestic consequences such as environmental pollution and deforestation, suppressed economic development, income inequality, food insecurity, and poor human health (Cavanagh and Hackel, 1983; Jorgenson, 2010). Land tenure regimes in extractive peripheral economies are often under the control and direction of the state (Bunker, 1985). But in the Kenyan flower industry, land and capital is almost exclusively owned by foreign investors and transnational corporations (TNCs) from the developed world (cf. Ngunyi, 2014). These characteristics make Kenyan roses a core product in more respects than not as it is owned and controlled by a quasi-monopoly of capitalists from the developed world who have geographically outsourced its production to Kenya. Apart from the embodied resources, there is nothing Kenyan about Kenyan roses.

Unlike other core products, rose flower production is labor-intensive. Many husbandry activities, harvesting, grading and packaging are difficult to mechanize. This unique characteristic is evident in the exchange of embodied labor (Fig. 13) which, as expected under the EUE theory, shows that at a fixed price, more embodied Kenyan labor is exchanged for less Dutch. Even though the difference seems to have diminished slightly over time, no factor-price equalization is discernible. This is reflective of the huge wage differential between the two countries. Kenyan cut flower workers earn slightly over a dollar a day

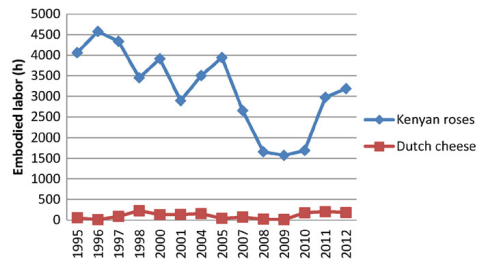

Fig. 13. Exchange of embodied labor at fixed (US$10,000) wage.

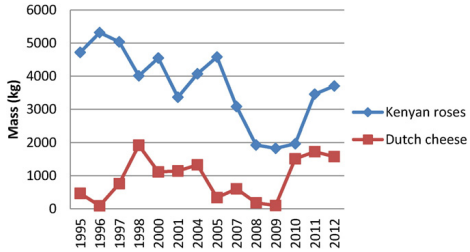

Fig. 14. Exchange of embodied mass at fixed (US$10,000) price.

(Dolan et al., 2003) while the minimum daily wage of Dutch workers is about US$93 (Ministerie van Sociale Zaken en Werkgelegenheid, 2013).

The exchange of mass per dollar also fits the EUE hypothesis (Fig. 14), but in terms of land (Fig. 10), water (Fig. 11), and energy (Fig. 12), The Netherlands seem generally to be losing embodied resources in trading its cheese for Kenyan roses. It seems that the potential for profit inherent in the great wage difference between the two countries has encouraged the establishment of labor-intensive cut flower production in Kenya, even though in terms of embodied resources it appears to contradict the EUE pattern.

5.3. Environmental Load Displacement

The gray water footprints and CO_2 emissions illustrate environmental load displacement, how a country shifts environmental burdens onto another or suffers burdens caused by another (cf. Muradian and O'Connor, 2001), a key characteristic of ecologically unequal exchange. Since they are displaced burdens rather than resources per se, quantifying their exchange per dollar was considered superfluous. However, their different potential impact on the target countries is worth noting. The gray water footprint is the volume of freshwater required to assimilate a load of pollutants based on existing ambient water quality standards (Hoekstra and Mekonnen, 2012). Unlike The Netherlands, Kenya is water scarce (cf. Marshall, 2011). The impact of even equal gray water footprints on the countries' environments and livelihoods can thus be markedly different. Although nations which import embodied CO_2 emissions in energy-intense products do not physically exert their carbon footprint on the providing nation but rather on the global commons (Moran et al., 2009), less developed countries are more vulnerable to climate change (cf. UNFCCC, 2007). Moreover, the offshoring of energy-intensive production stages increase air pollution and can have significant health and environmental consequences in the receiving country.

6. Conclusions

This paper develops and tests an LCA-based methodology for estimating ecologically unequal exchange (EUE) and rejects the ideology of market reciprocity, a key EUE mechanism. In combination with flow data on embodied materials and energy in relation to exchange values, the practicability of the methodology has been demonstrated for trade in specific flagship export commodities exchanged between Kenya and The Netherlands. Although the methodology was applied to specific products, the same approach can be extended to entire economies. This is an area for future research. It should be emphasized here that EUE between two countries or regions can only be conclusively determined if most or all exchanged products are considered in a total physical trade balance (PTB). Such analyses are made easier if comprehensive national product LCA inventories and databases exist. A number of core countries have or are in the process of developing such inventories (cf. Rochat et al., 2013; Thrane and Schmidt, 2007; Van der Voet et al., 2005; Weinzettel and Kovanda, 2009). Not so with many peripheral countries. Such efforts offer a double dividend as they serve regular LCA applications in addition to allowing estimation of EUE.

Ecologically unequal exchange can be demonstrated in several ways, but the clearest illustration is through consideration of the quantity of embodied biophysical resources exchanged per dollar or other unit of exchange value. By holding market price constant, we are able to quantify the asymmetric resource transfers, as well as test a key mechanism through which EUE occurs. This helps empirically lift the veil off the discursive filters and illusions which continue to sustain the free market ideology as fair or tantamount to reciprocity.

Since monetary valuation evidently obscures biophysical unequal exchange, integration of biophysical metrics alongside monetary valuation in international trade is imperative. Revelation of EUE may motivate interested actors and schools of thought to respond differently. One possibility would be the urge to promote certain products in line with the traditional persuasion to pursue comparative advantage, another to try to negotiate 'better' prices in an attempt to 'internalize externalities.' However, such efforts are most likely doomed to fail so long as they do not address the underlying structural and skewed power relations at play. Ultimately, a rethinking of the structure, politics and policies of the international capitalist system of resource exchange is necessary.

Acknowledgments

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