On Elephants Not in the Room

The Paradox of Sustainability versus Economics, and A Case for Interdisciplinary System Economics

Tobias J. van Bakel

Master Thesis in Culture, Environment and Sustainability

Centre for Development and the Environment

UNIVERSITY OF OSLO

2019

2019

On Elephants Not in the Room - The Paradox of Sustainability versus Economics, and A Case for Interdisciplinary System Economics

http://www.duo.uio.no/

Print: Reprosentralen, University of Oslo

Abstract

This thesis is a theoretical examination of the problematic relationship between sustainability and the orthodoxy in economics disciplines and practice—characterized by neoclassical theories and assumptions. For this purpose, the use and history of sustainability is critically assessed, the three dimensional model rejected, and a meta-framework proposed instead, starting from 'to sustain'; consisting by definition of both a normative and a scientific criterion, without a-priori filling in what 'to sustain'. Sustainability is thus operationalized as *certain* 'ends' towards which *certain* economics are 'means'—in this relation both sustainability and economics can be critically assessed as, respectively; 'possible and desired ends', and 'possible means' towards these 'ends'. With this framework orthodox economics' socio-political delineations of economy, with external environment(s) framings, are juxtaposed against the social and environmental relations that constitute the 'anthropogenic economic activity'. What constitutes past productivity 'growth', or efficiency increases of anthropogenic activity within system Earth, are argued at length to pertain to social and environmental cost-shifting practices. In the context of a full(er) world system Earth; with a relatively diathermically closed thermodynamic workings; in state of ecological overshoot, and anthropogenic climate disruptions, the environmental shifting of costs are argued to be impossible thus leading by definition to accelerated system degradation—thus increasing socio-environmental costs—if the same empty-world economic logic remains the orthodoxy. The discussion concludes that the relationship between sustainability—in the proposed double-criterion model—and neoclassical orthodox economics is therefore contradictory; i.e. the latter amounting to 'uneconomic economics'. Thus an interdisciplinary approach to economy is called for allow for more accurate accounting of socio-environmental costs and benefits in changing system Earth's economy; a meta-framework of '*system economics'* is cautiously proposed for this purpose, to be expanded upon through further research.

Acknowledgements

I want to acknowledge and thank my supervisors: Arve Hansen, and previous supervisor Desmond McNeill, for their council, their valuable input during the project, and for the interesting, thought-provoking, and enjoyable discussions during supervision meetings over the course of this project. I also want to thank the Senter for Utvikling og Miljø in Oslo, and in particular Anne-Line and Gudrun for their support and for giving me the time to finish this project.

Table of Contents

List of figures

Abbreviations

ES	Ecosystem Services
GDP	Gross Domestic Product
MEA	Millennium Ecosystem Assessment
NGO	Non-Governmental Organization
SD	Sustainable Development
UN	United Nations
UNCHE	United Nations Conference on the Human Environment
UNEP	United Nations Environmental Programme
US	United States
WCED	World Commission on Environment and Development
WSSD	World Summit on Sustainable Development

Introduction

As a collective of human beings on Earth bound for the most part by its physical atmospheric boundaries, we have become ever more interconnected and interdependent in scale and intensity on each other and our environments. Through global population growth, expansion and intensification of socioeconomic, socio-political and cultural relations across time and space and increased material accumulations and transformations of 'natural capital' we have changed some of the workings on planet Earth of economic relevance to us significantly in the aims of satisfying for our wants and needs. Guided by academic theories and socio-political practices of economics as social and environmental cost-displacements and investments we have thus changed our institutions and structures for production, provisioning, (re)distribution, and consumption on the one hand, and the environment(s) on Earth on the other—through increasing our aggregate footprint (see Meadows and Randers 2012; Wackernagel and Rees 1998; Wiedmann et al. 2015).

The impact on the macro (i.e. global), meso (i.e. national), and micro (i.e. regional) social and ecosystems and other system relations—such as climate(s)—through ever increasing economic development to satisfy both human needs and wants has proven to have detrimental feedback effects on our abilities to safeguard satisfying precisely those same human needs and wants (see Adams 2014; Constanza 2012; MEA 2005; Meadows et al. 1972; Meadows et al. 1992; Meadows and Randers 2012). The impacts on our ecosystems across scales has however not been 'equally' distributed nor felt as equally in both negatives and positives; instead the felt impacts cutting across socio-political spatial—for example between countries—and socio-economic lines—i.e. 'wealth' strata within countries—generally affecting those with relatively less material wealth and lower socio-political power harder than those with relatively more material wealth and socio-political power (see Escobar 1995; Escobar 2015; WCED 1987). The diverging consumption or energy-matter throughput patterns furthermore relate to significant differences in economic development; meaning 'responsibility' for the environmental and socio-economic impacts on macro, meso, and micro levels of system Earth not being 'equal' either.

Sustainability has been presented over the past decades as *the* solution to these and other 'development' problems in major academic and socio-political debates. The concept its popularity seemingly reaching new heights every decade since its 'formal' introduction in 1987 (WCED 1987) to a point of near-unanimous acclaim across academic and socio-political debates as being *the* goal of human development—and through sustainable development *the* means towards it. The concept however has remained vague and a consistent *agreed upon* (non-paradoxical) operationalization of sustainability has remained elusive in both the academic and socio-political debates.

The concept has been internalized into the language of neoclassical orthodox economics, as has become reflected in economic sustainability being represented as a requirement alongside environmental and social dimensions of sustainability—where the social can be considered as socio-economic alternatives to orthodox economics. An *apparent contradiction* emerges then—i.e. a paradox—or possibly an *actual contradiction*, that regardless has to be addressed in order to move sustainability beyond its merely symbolic significance and downright ineffective usage. For the origin of sustainability posed a challenge to the very theories and practices of orthodox economics that continue to call for increasing our impact on our environment(s) on Earth, now under the umbrella of economic sustainability.

I. Aims, key questions, and methodological approach

There is a considerable gap in the current (dominant) academic and socio-political debates on sustainability where the supposed pillars or dimensions sustainability, and corresponding advocacies and disciplinary 'boundaries' are *not* taken for granted as sovereign and independent in nature. Despite continuous calls for sustainability as lying in the interactions between them this gap remains (see Daly 2015; Ferguson 2015; Gendron 2014; Lehtonen 2004; Meadows and Randers 2012; Rees 2015; Söderbaum 2015; Spash 2012a).

This thesis aims to examine the elephant in the room that is the paradoxical or contradictory relationship between increasing sustainability in its 'popular' three dimensions modeling, and economics—in particular the dominance of neoclassical economic assumptions that frame the orthodoxy. For this aim it is necessary to deconstruct both the 'popular' sustainability conception and the taken for granted orthodoxy of neoclassical economics. A system theory approach will be employed to both highlight the importance of interdisciplinary approaches to economics and sustainability, and to propose a framework for 'harmonizing' the relationship between them for the goal of increasing sustainability of the Earth system its economy. This thesis aims to contribute to understanding of sustainability and economics (new form), and the author hopes to contribute with the proposed frameworks for sustainability and *system economics* through the discussion in this thesis. The key questions that this thesis will examine with the above stated aims in mind:

1) Is the relationship between sustainability and neoclassical orthodox economics better characterized as one of paradox, or one of contradiction?

2) How can the concept of economy be framed within an interdisciplinary system theory where 'the environment' and 'the social' are entirely internal?
3) What philosophy of science characteristics can serve to foster a more interdisciplinary approach to economy and sustainability?

This project is theoretical in nature, has followed a methodological approach of primarily literary review—this thesis thus presents a theoretical treatise. Due to the scope of the subject, and in particular the aim of discussing a significant research gap in interdisciplinary approaches to sustainability and economics—i.e. *between* mono- and multi disciplinary approaches—a 'smaller' more concise case study or statistical approach was deemed as inadequate for the aim and analytical level of this project. The emphasis in this theoretical examination and assessment lies in an approach characterised primarily by a critical realism philosophy of science, ecological and institutional heterodox economics, political economy, and sociological-philosophical understanding of normativity and value. With the aim of an interdisciplinary approach this author has attempted to start the discussions in this project outside of clear singular disciplinary boundaries, which is explicitly discussed in depth in chapter three leading to a proposed approach termed '*system economics*'.

II. Outline and structure

This projects starts in chapter one with an in-depth discussion of sustainability in order to frame a workable concept to function as operationable independent variable; i.e. as the *certain ends* towards which *certain* economics is the *means*. For this purpose the explicit re-institutionalization of the concept over the preceding decades is discussed. An academic consensus is presented and agreed up with that sustainability is too abstract and paradoxical in its 'popular' socio-political and academic form (see Appleton 2006; Bartlett 1994; Christen and Schmidt 2012; Connelly 2007; Dawe and Ryan 2003; Egelston 2012; Fricker 1998; Fergus 2005 Lehtonen 2004; Harlow et al. 2011; Huge and Waas 2013; Kemp and Martens 2007; Redclift 2005, Söderbaum 2011; Söderbaum 2014). The concept of sustainability is then deconstructed down to pertaining to both a normative and a scientific criterion—A meta-framework is proposed to move the concept beyond its popular though paradoxical or contradictory stranded position, and to move away from *mono*- and *multi-disciplinary* approaches to sustainability towards more consistent *interdisciplinary* approaches.

Chapter two continues with the focus on the framing of sustainability in its three dimensional model(s); in particular the discussion juxtaposes environmental assessments—from primarily ecological and ecological economics approaches—to neoclassical orthodox economics approaches to its supposed 'external' environment(s)—if the environment is considered at all within it. Changing scarcity patterns over the past two centuries and the lack of corresponding change in neoclassical orthodox economic theory and practice in regard to the environment are discussed with the help of Daly's (1992a; 2015) empty and full world economics concepts. A central theme starting from chapter two is to critically assess what 'economy' is seen to be; originating from the same greek *oikos* ('household') that ecology is derived from. As well crucially on the other side of the same coin; what is argued to not fall into 'economy'—and thus is 'external'. A deceivingly simple line of questioning of the taken for granted field and epistemology of orthodox economics with its external environment (see Adams 2014; Adkisson 2009; Daly 1992b; Gómez-Baggethun et al. 2010; Gómez-Baggethun and Ruiz-Pérez 2011; Kapp 1976; Martínez-Alier 2002; Peterson et al. 2010; Söderbaum 2015; Spash 2012a; Tacconi 1998; Vatn and Bromley 1994).

The results from this line of questioning and the presented discussions are likewise deceivingly simple; everything is economy. That is to say that through the system theory approach that will be proposed the *system's economy* has to be considered holistically to where the system can be considered *relatively* 'closed' or isolated. The (neo)classical orthodox economic framing of economy, as an economy delineated by socio-political boundaries—such as a country—is discussed in relation to classification of a system as 'open' (sub)system, closed, or isolated. These socio-political boundaries and neoclassical orthodox economics—hereafter generally referred to as simply 'orthodox economics—its articulations of these are critically assessed in relation to the social and environmental relations crossing such boundaries, and the implications to economy delineations discussed. The implications of such framings being contradictory to i.a. presented ecological and socio-economic alternative accounting of economy.

In chapter three the impetus for the need for a system theory interdisciplinary economics is then addressed through the proposed *system economics*. A philosophy of science is proposed and extensively discussed through the parable of the blind men and the elephant (Saxe 2017[1892]), and aided by critical realism philosophy (see Archer et al. 2016; Dow 2007; Rutzou 2016; Spash 2012a; Spencer 2017; Tacconi 1998), in an attempt to frame a *system economics* that allows for both objectivist and relativist epistemologies to come together for non-paradoxical and non-contradictory accounting of the *system's economy*. The discussion is obviously limited by the scope of this project and the thesis—thus representing merely a proposed meta-framework that requires further debate and research to be made practical. Much of the discussion in chapter three revolves around two premises: Firstly that facts and values are exhaustive and mutually exclusive concepts—they are not easily separable from each other and are to varying degrees mutually constituted, where thus critical assessment is possible within examining this relationship. Due to inherent epistemological limitations of human beings we cannot avoid subjectivism of facts, nor crucially that values contain within in them and are based on suppositions of facts (See Knox-Hayes 2015; Rutzou 2016; Sayer 2015; Spencer 2017).

Secondly, a premise that both 'seeing is believing'—indicating that what is 'observed' and 'measured' constructs our understanding of reality (positivist epistemology)—and in addition that 'believing is seeing'—indicating that our constructions of reality and epistemological claims to facts and knowledge frame what think and argue reality to be; therefore influencing how we *try* to restructure reality to our 'believe' of it. This premise is applied in the frame of this thesis to how an impoverished notion of economy through neoclassical orthodox economic theories, practices, and institutions has degraded its own foundation, which the next chapter will expand upon through i.a. discussion of thermodynamics and economics

In chapter four a 'wider' definition for economy is proposed through a system theory approach: an economy being a system delineation of an open, closed, or isolated system—where accounting for an open system its economy is a-priori deemed problematic due to relations crossing its boundaries being considered 'external'. Valid in articulation 'an economy' its borders and accounting for the 'economic activity' within it—irrespective of this activity being anthropogenic or not—determines effectiveness of restructuring or developing the system's economy towards desirable state(s). In relation to this proposed system framing for *all* economics, physical limitations to development and scarcity implications of the closed *system's economy* of system Earth are discussed. The thermodynamics of a relatively closed system as part of the accounting for the *system's economy* are discussed in depth in chapter four. Particular emphasis in the discussion is given to how this structures possibilities for (economic) development or transformations and (economic) maintenance of desirable system state(s)—aided by the concept of dynamism and novelty by combination to emphasize both; the structured embeddedness of the socio-environmental within the physical on the one hand (see Boulding 1966; Georgescu-Roegen 1971; Zencey 2013), and the limited dynamism this frames for socio-economic goals of biophysically constituted human beings.

The thesis closes with several topics of discussions relating to the implications of the preceding discussions and the proposed meta-frameworks for sustainability as a measure of validity for ends, and *system economics*—with the proposed *system's economy* of system Earth as the valid field; the valid *oikos*—reframed as measure of validity for means. Finally, several cautious concluding remarks are made on the basis of the presented research and discussions.

III. The elephant in the room?

'The elephant in the room' is a metaphor used to describe a subject that is generally or by a majority ignored in a discussion. An elephant is an animal of substantially large size compared to even the tallest human being and not easily ignored, least of all if it would be squished inside of a room not made for elephant proportions, in fact, it would leave little to no space for the discussion to continue. The metaphor thus applies to a subject that is nearly-impossible to be unconsciously ignorant of, yet is left out or ignored in the discussion. So too is in the economics and sustainability discussions the seemingly contradictory—paradoxical—relationship between these an elephant in the room. As the following chapters will discuss to try to arrive at a judgement on whether the relationship that the metaphorical elephant embodies is one of paradox or one of *actual* contradiction, and propose solutions towards resolving this troublesome relationship—be it a paradox or contradiction. For this purpose sustainability and orthodox (dominant) economics need to be demystified and critically assessed.

Chapter 1 Framing the Sustainability Problem

1.1 A picture frame on the wall

The wide usage of the noun ‘sustainability’ as well as the adjective of ‘sustainable’ in governance of provisioning, academics, and politics is generally credited to the publishing of Our Common Future by the World Commission on Environment and Development in 1987 (WCED 1987). As Appleton (2006: 4) notes: “*The noun is so new that it is not even defined in the 1987 edition of one of the more comprehensive standard English dictionaries.*” The report, commonly referred to as the Brundtland report, provided a formalized definition that has become authoritative to the concept of sustainability and both its theoretical and practical application as both and a noun and an adjective (e.g. sustainable development).

> “*Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*.” (WCED 1987: 15).

The words, and the concepts of sustainable and sustainability, come from the verb ‘to sustain’; derived from the latin verb *sustinere* meaning ‘to uphold’, and as well relate to usage of ‘sustenance’ as ‘the means to sustaining life’ (see Appleton 2006). The most basic question then that sustainability in its various forms calls out—but too often left unanswered is: to sustain what? (Dobson 2012; Ferguson 2015; Meadows and Randers 2012).

Certainly the publishing of the Brundtland report can be marked as a historical marker for the explosion in usage of the adjective sustainable and the noun sustainability. Though often presented as a paradigm shift, what sustainability refers to is not a new concept. Maintaining, preserving, and continuation are arguably concepts that—irrespective of degree of consciousness of it, or degree of explicit articulation of it—have been at the forefront of humans and our social organization of economy; i.e. the anthropogenic economy, and arguably at the forefront of all forms of life. After all, life concerns survival of individuals, groups of individuals, and entire species—up to sustaining the ability of system Earth to sustain ‘life’ in its specific manifestations as we know it. Human beings as biological entities ourselves are *part* of this system Earth, and thus relate to interdependencies of species and various other system relations that frame system Earth such as ecological, climatological, and hydrological relations.

The frame of sustainability, beyond its popularized institutional Brundtland definition, concerns maintaining a specific configuration—i.e. *certain* state(s) of a system. These system states pertain to a *certain* stability of *certain* configurations of a *certain* system construction—projected over a *certain* measure of time. More simply put, the 'where' or system delineation; the 'what' or system state; and the 'how long' or its temporal projection. An admittedly rather abstract reframing, purposefully so however in order to highlight that these variables are not reducible to a singular measure of 'sustainable' or 'sustainability'; expressed and questioned in a self-contained simple 'is it sustainable?'.

The obvious question then; how does the picture of institutionalized and popularized sustainability—as both socio-politically and academically widely used—'fit' within this frame? The discussion will then continue with a brief critical examination of how validly this popular conception of sustainability (WCED 1987) can be used intersubjectively and between disciplines as a measure to fit the frame. On the basis of the outcome of this examination the simplified framework of 'where, what, and how long' will be extended upon—with the aim of constructing a concept and operationalization of sustainability that allows for further discussion of the research questions of this thesis within an interdisciplinary framing.

1.2 The problem statement and institutionalization

The modern (re)institutionalisation of sustainability finds its roots amidst environmental crises of the early 1970s. During the early 1970s concerns over ever increasing rates of world population growth, continuing poverty levels, higher awareness of environmental degradations, and certain resource (distribution) shortages led the Club of Rome to publish the first The Limits to Growth report in 1972 (Meadows et al. 1972) (see also Appleton 2006; Bartlett 1994; Hens and Nath 2003).

The Limits to Growth report expressed hard quantitative limits to what the Earth could support. Its (still) controversial statement was that growth could not be indefinitely sustained in a relatively closed system such as the Earth. In doing so the report challenged directly the economic growth paradigm that is (still) a crucial, if not inseparable foundation of neoclassical orthodox economics—i.e. the established, taken for granted; the relatively unquestioned hegemonic discourse on economics. Such a challenge to dominant economic theories was not necessarily new. However, amidst increased attention and expressions of alarm over environmental and social concerns The Limits to Growth stood out in prominence with its format of a 'hard' quantified model. The report included as well extrapolations of the model for projections into the future in various scenarios, and provided recommendations for corrective policies and actions (Bartlett 1994).

The exclamation of limits being applicable to economic and social development found praise from those who raised concerns over environmental degradation—and social concerns, often resulting from such degradation generally affecting disproportionally the socio-economic poor. The report garnered considerable criticism and ‘swift, urgent, and immediate rebuttal’ from those who have long argued for the saving grace of continued—if not ever-increasing—economic growth (Bartlett 1994; Cole et al. 1973). Bartlett (1994) furthermore notes that the criticism perhaps originated as a shock to the report’s prognosis of limits, and its foretelling consequences of crossing these, being “*too terrible to be true.*” (see also Meadows and Randers 2012).

The same year that The Limits to Growth was published the United Nations Conference on the Human Environment (UNCHE) took place in Stockholm. It was marked as the first global intergovernmental conference on the environment and socio-economic development. Over the next decades similar conferences were to be held once every ten years. The UNCHE resulted in the establishment of the United Nations Environmental Programme (UNEP) in Nairobi, environmental ministries in over a hundred countries, and an ‘explosive’ increase of NGOs with primary focus on environmental protection. Thus the UNCHE is attributed with having resulted in environmental issues being given a more prominent position on the international agenda—prominence that would also be reflected in the outcome document of the UNCHE that was dubbed the ‘Stockholm Action Plan’ (Woodruff 2012; Hens and Nath 2003).

Ten year later the United Nations General Assembly requested a ‘Session of Special Character of the Governing Council’ from the UNEP in Nairobi. An oft forgotten conference referred to as ‘Stockholm+10’ or simply ‘Nairobi’ (Egelston 2012)—the session’s goal was to assess progress on the Stockholm Action Plan over the preceding years since the UNCHE. The conclusion had a pessimistic outlook, as little concrete progress was judged to have been made since 1972 (Egelston 2012). At the Nairobi conference developing countries insisted on including human interactions with the environment more into the environmental agenda. Their advocacy proved however at odds with developed countries’ continued orientation—as theirs was more represented in the Stockholm action plan ten year prior—best characterised as a technological and technocratic focus towards the environment and reducing environmental degradation. A fact also reflected in the problem statements themselves in relation to the environment problems. This clash between the established environmental agenda and developing countries also reflected changes within socio-political and scientific debates—as paradigms shifted over the preceding years since the UNCHE. The resulting fragmentation restricted the UNEP’s efficacy on advancing the environmental agenda put forth by the UNCHE (Hens and Nath 2003; Egelston 2012).

Though little-known, and notably absent from historical accounts of sustainability, the Nairobi conference—or Stockholm+10—is significant as a marker for more consideration towards socio-economic drivers of environmental problems (Hens and Nath 2003; Egelston 2012). Crucially, the inclusion of the social and the economic dimensions into, and related to the environmental agenda, led to a motion from Nairobi through the UN system for the establishment of a special commission to consider environmental strategies into the next millennium. The resulting commission—formed in 1983—would be chaired by Norway's former Prime Minister and Minister of Environment Gro Harlem Brundtland. The commission would carry the name of World Commission on Environment and Development (WCED), thus reflecting the paradigm shift observed in Nairobi. The social and economic development and the environmental agenda, though still considered as relatively separate spheres, were now firmly linked together in the environment, economics, and development debates—or what thereafter could be framed by the terms of sustainability and economics debates (Hens and Nath 2003; Egelston 2012; Clark 2013).

In 1987 the WCED would publish its now famous oft-quoted Our Common Future report (WCED 1987)—which has become also known as the 'Brundtland report', named after the commission's chair Gro Harlem Brundtland. The report built on the legacy of The Limits to Growth (Meadows et al. 1972), the UNCHE, and Nairobi. It now *formally* linked the environmental agenda with economic development and human interactions, with their environments together, and provided a definitional term that corrective measures towards improving these now linked dimensions would carry; Sustainable Development (SD) (Clark 2013; Hens and Nath 2003). The conclusion the report made was that the environmental agenda could not effectively be addressed without addressing the problem of poverty. What the report brought forward as the corrective measure was SD—as a different kind of 'growth'. This different kind of growth would be socially inclusive and non-harmful to the environment, as opposed to the kind of growth that had caused the environmental degradation and socio-economic disparities (Harlow et al. 2011; Kemp and Martens 2007).

The formulation of the report, and the concept of SD can be framed as a stroke of political genius; uniting previously oppositional interests and advocacies under one umbrella concept (SD)—a concept that all readily agreed to and few if any would oppose in name; for who would not want poverty reduction, economic growth, and (increasing) environmental stability if it would all come without cost to their own interests? The concept in its WCED formulation represents a socio-political outcome that allows widely varying—and arguably opposing—interests and advocacies to legitimize *their* interpretations and advocacy of interests through the same definition (Söderbaum 2007; Hugé et al. 2013). The concept of

SD as came forth through Our Common Future (WCED 1987) *seemed* to resolve the stalemate between environmentalism and economic interests that marked upheaval at the 'emergence' of major environmentalism in the 1970s. Furthermore, the concept *seemed* to resolve the stalemate between the technological and technocratic focus in the environmental agenda of the 'North', and the focus on poverty reduction of the 'South' of the early 1980s. The concept of SD thus conceded and legitimized both human 'needs' and 'wants'—without judging a distinction between them—and safeguarding environmental resources for future generations (Appleton 2006**)**.

However, as the old adage goes, when something seems too good to be true, it probably is so—as the key question of this project relating to the paradoxical or contradictory relation between sustainability and economics indicates. While SD provided a frame for opposing interests and advocacies in which they could all see their interests and advocacies reflected, it can be argued to have provided no proverbial picture of *actual* agreement to hang inside the frame. Unsurprising then, operationalization of the Brundtland definition of sustainability tends to very quickly degrade back into the underlying divisions that it *seemed* to resolve as SD has become so widely used a term by all these advocacies and interests involved.

1.2.1 Limits versus sustainability

The emergence and wide adoption of the adjective 'sustainable' after 1987 is not radically surprising when contrasted with the call for limits as exemplified by The Limits to Growth (Meadows et al. 1972). Whereas the concept under the message of limits directly challenged socio-economic goals of 'growth' and intensive socio-economic development in (in)direct relation to their environmental and social impacts; 'sustainable'—as an adjective to e.g. development and economy—allowed for a certain agnosticism towards limitations due to its imprecise definition and relatively (perceived) novelty of the concept.

The word 'sustainable', as used in the WCED report (WCED 1987), was drawn from the concept of 'sustained yield' as used in forestry since at least the 18th century (see Scott 1998; Wiersum 1995). The concept of sustainable yield in forestry meant to indicate careful, measured exploitation and maintenance of forest resources in such a way as to ensure future exploitation 'indefinitely'. A focus on the logical continuation of a process within, or of an entire system its state; *sustained* into (theoretical) perpetuity. In contrast to The Limits to Growth its exclaimed limitations—a focus on logical discontinuation or even reversal of 'growth'. Limits presented a message of warnings and of thresholds—in other words for the necessity to slam the brakes at a stop sign: Change speed or course, or face the consequences.

The message of sustainable provided a more 'comforting' and 'reassuring' vision; as the adjective was attached to aforementioned issues of concern that the message of limits in the preceding decade brought to the fore—such as *sustainable* population growth, *sustainable* economic growth, *sustainable* development, *sustainable* energy and resource consumption (Bartlett 1994). Bartlett (ibid) furthermore poses that one can perhaps even consider the rapid popularity of the adjective of sustainable as an offset or deflection strategy towards the message of Limits. The framing, its imprecise definition, and operationalization of sustainable from its origins in sustainable yield and the WCED (1987) proved far more compatible with the *continuation* of dominant socio-economic interests, than the message of limits and the language of *discontinuation* allowed for.

1.2.2 Rio and beyond

Five years after the publication of Our Common Future (WCED 1987) the United Nations Conference on Environment and Development (UNCED) was held in Rio de Janeiro in 1992. The focus of the UNCED—commonly referred to as simply 'Rio'—was on further linking environment and development together within one agenda, and building on the definition of SD put forward by the WCED. The UNCED furthermore resulted in the notable prescription that SD applied to countries in all 'stages of development', and not just for the developing countries in the 'South', but crucially also for the consumption-heavy 'developed' countries in the 'North' (Bartelmus 2013; Redclift 2005).

Despite establishing a linkage between economic, social and environmental concerns—and building wide support for SD—little practical agreement had been fostered on what balance or relationships between these SD should be comprised of (Hens and Nath 2003; Lehtonen 2004; Woodruff 2012). It was from the UNCED in Rio de Janeiro that the now classical three pillar model of sustainability emerged—the environmental, the economic, and the social dimensions, or pillars. Notably such a distinction between three separate distinguishable dimensions was not explicitly modelled by Our Common Future (WCED 1987). The three dimensional framing would become the basis for most operationalizations and definitions of sustainable, sustainability, and SD in the rhetoric of governance, NGOs, and businesses alike—which is still reflected in both academic and socio-political debates (see Lehtonen 2004). This basis can also be found translated into similar models such as the 'triple bottom line' of People, Planet, Profit (PPP), a popular operationalization in for instance, business rhetoric and orthodox economics (see Dawe and Ryan 2003; Lehtonen 2004).

The year of 1992 also marked the publication of the twenty year follow-up to The Limits To Growth (Meadows et al. 1972). Titled 'Beyond the Limits' (Meadows et al. 1992), this publication examined the global developments of the preceding twenty years, and used this data to update and test the accuracy of the models used for The Limits to Growth—resulting in confirming the message of limits. In addition however, Beyond the Limits added a conclusion that through the past twenty years increasing (economic) development—in ignorance of the limits articulated in The Limits to Growth models—the carrying capacity of system Earth's ecosystem had been crossed. In Beyond the Limits Meadows et al. (1992) thus warned that there was no longer a case of cautionary limits for the future, but that the then present case was one of 'overshoot', to what system Earth could support over long(er) terms. The message—in 1992—thus changed from avoiding limits to one of already having past these limits, and thus the need for reduction; or 'backing down' from the overshoot state (Meadows et al. 1992; Meadows and Randers 2012).

Ten years after the Earth Summit at Rio (the UNCED), in 2002, another Earth Summit titled; World Summit on Sustainable Development (WSSD) was held in Johannesburg. Here progress towards sustainable development and environmental 'quality' over the past ten years since the previous Summit was assessed. The conclusions showed that little to no progress had been made towards increasing SD, as many environmental indicators in fact showed further degradation since 1992. Though consistent operationalization of SD had remained elusive, assessing what was *unsustainable* in variables such as environmental degradation and socio-economic disparity such as poverty proved less problematic. The lack of progress was primarily attributed to lack of practical implementation and thus consistent operationalization for SD. The WSSD marked however increased involvement of the private sector into the summit itself, which was hailed as a positive marker towards attempt to 'revitalize' the concept of SD (Bartelmus 2013; Hens and Nath 2003).

Another ten years would pass until the next conference—held in 2012 in Rio de Janeiro to mark twentieth-year anniversary of the first Earth Summit in Rio in 1992. The United Nations Conference on Sustainable Development (UNCSD)—commonly referred to as RIO+20—argued for 'greening the economy' and further shifted the focus of SD towards the language of (orthodox) economic development and business (Bartelmus 2013; Woodruff 2012). The outcome of the conference, titled 'The Future We Want' (UNCSD 2012) did little to progress SD towards a more consistent operationalization, nor did it address the underlying diverging interests and advocacies at odds with one another. The outcome document instead reflected a recommitment to (orthodox) economic growth—in the form of the discourse of ‘green growth’ and the ‘green economy’ (see Ferguson 2015; Spash 2012b).

The year 2012 also saw publication of an update to The Limits to Growth (Meadows et al. 1972; titled ‘The Limits to Growth: The 30-year Update’ (Meadows and Randers 2012). Written over the ten year prior, The 30-year Update reflected upon the past years since both The Limits to Growth and the Beyond The Limits publications. It concluded that the overshoot had increased, whilst socio-economic sustainability of ‘increasing consumption for the world’s poor’—i.e. relative wealth and welfare distributions and biophysical need satisfactions—was still beyond reach, despite the ever-increasing global overshoot of humanity its collective ecological footprint. Meadows and Randers explicitly state in their preface—written in 2004—that through the ‘well-intentioned but halfhearted’ debates on sustainability humanity wasted the past thirty years (Meadows and Randers 2012).

1.3 Circles and pillars - On sovereignty and hierarchy

> “*All the examples of this sustainable development model emphasize two main points. (1) To achieve sustainable development, we must consider the environment, social well-being, and economy as the legs sustainable development stands upon. (2) We must consider each leg equally—although the three legs are separate, they are of equal importance.*” (Dawe and Ryan 2003: 1459).

The three dimensional model—consisting of the environmental, the economic, and the social—is generally expressed both visually and descriptively as three pillars, which only through their combined strength are able to ‘hold up’ SD or sustainability (see Dawe and Ryan 2003; Lehtonen 2004). This representation frames three hierarchically equal dimensions with a-priori specific application or context equal importance, and with each pillar or dimensions pertaining to a relatively sovereign category—i.e. self contained, self evident, relatively exhaustive, independent, and governed by relatively sovereign logic as reflected within both academic and socio-political debates. The model represents the idea that it is only through the carrying capacity of all three equal pillars combined that sustainability can be achieved and ‘supported’—an idea that has found its roots in the political legacy of the establishment and institutionalization of the concept of sustainability as discussed in earlier in this chapter.

Alternatively the three dimensional model is sometimes represented as three circles; party overlapping each other thus resembling a Venn diagram. Where a circular representation differs notably is in the three dimensions having *some* overlap between them at their borders to each other—thus representing a more critical view towards the sovereignty and independence representation of the pillars model. The pillar model seems to however be more representative of the dominant approach to sustainability and economics. As interests and advocacies are rather firmly categorized in their 'relevant' dimension, and interactions conceived of as external linkages to the other dimensions across their own 'hard' dimensional borders. Furthermore a similar framing exists in the dominant academic debates on sustainability and economics in adherence to structural division of e.g. ecology, orthodox economics, and development-oriented social sciences.

1.3.1 The three dimensional sustainability model

Lehtonen (2004) identifies several main valid criticisms against the three pillar model of sustainability that illustrate the previous stated arguments: Each of the three pillars has its own logic and criteria that are often seemingly irreconcilable to each other—as can be illustrated by considering the actors and disciplines that represent and advocate the interests of the different dimensions. The following—admittedly crude—framing of these divisions is presented for illustrative purposes: The economic can be considered guided by an orthodoxy of neoclassical economic theories and a general (claim to) a natural scientific approach to production, provisioning and resource allocation, and consumption. This orthodox economic logic and criteria generally pertain to status-quo power relations; a focus on a singular commensurate measure of 'wealth'—objectified exchange values articulated in 'money'—and are both advocated through governments, businesses, and lobbies, and looked towards as the panacea for environmental, economic, and social problems as well. The social can be argued to follow a general logic of relativism and disciplines founded on constructivist epistemologies. The social logic and criteria generally align with challenging status-quo power relations; a focus on improving welfare rather than wealth and thus measured and articulated in more diffuse non-commensurate variables; and is advocated through civil society such as NGOs, social sciences and 'developing' countries. The environmental is guided by i.a. ecological, climatological, and to a lesser degree social sciences. The prevailing logic and criteria can be argued to be primarily that of natural science and a focus on non-anthropogenic environment. The environmental is generally advocated by NGOs with a primary focus on environment (with diverging concern or advocacy for human-environmental relations).

Thus, when inevitable conflicts arise between the different interests the dimensional or pillar model does not provide any criteria for distinguishing importance of the dimensions in any given context—nor does it thus allow for effective arbitration. Such conflicts are then the rule rather than the exception, one can, for instance, imagine the ever present conflict between the short(er) term focussed orthodox economic incentives and rationale for resource extraction—in the argument for creating more wealth or welfare in the social—and ecological or eco-economic stability for long(er) term incentives and rationales. Obviously these will rarely line up with each other—as evidenced by the 'environmental crisis' that led to the impetus and call for limits and sustainability. The three dimensional model allows for actors to argue that all three sovereign dimensions carry equal weight and importance, regardless of context or of validity which presents a paradoxical framing of the environmental-economic-social reality at best, and a contradictory one at its worst. The three pillar or dimensional model thus allows for little consistent or valid arbitration of the opposing interests—any conflict between the 'pillars' being likely to open old wounds that the political consensus 'victory' of sustainability was intended to heal or resolve in the first place.

The three pillars model thus serves to reify the advocacies that led to the political 'agreement' that the WCED (1987) definition of sustainability expressed, and the following Earth Summit embodied (Kemp and Martens 2007). Thus the three pillar and dimensional model is more likely to reinforce, reify, and legitimize the states quo and current theories and practices—including the orthodoxy of neoclassical economics, rather than to change it (see Lehtonen 2004). The theme of the two characteristics identified to the three dimensional model of sustainability; non-hierarchy, and sovereignty as a-priori, or assumptive pre-analytical principles will be returned to throughout this thesis, and form a central thread through the socio-political and academic discussions and the frictions therein relating to sustainability and orthodox economics.

1.4 The proverbial devil in the details

Sustainability—as the problem statement originating from the environmental crisis—rose from socio-political and academic awareness of the environment, leading to an outcome negotiated with politico-economic interests, to arrive at the commonly agreed to problem statement of sustainable development. The question begs to be asked if—in this negotiation process and thus reflected in its outcome—the problem statement changed. As the inclusion of alternative socio-economic concerns from developing countries in the global 'South'—and from within 'North countries through civil society and academics—was acknowledged and embodied in the problem statement of SD; likewise did the problem statement change beyond merely inclusion of the social dimension?

Sustainability and SD—having been firmly put and kept on the agenda—boils down to a deceptively simple problem statement of: 'the current situation is not-sustainable'. Three main variables divide up the problem statement further, per interest, advocacy, or discipline—in other words the actors: Firstly; the current 'as-is' state of the system is not-sustainable; in *certain* partiality, or a degree of its whole system state—therein a further division is important to distinguish in the question of whether the *same* partiality of the whole system state is deemed not-sustainable. Simplified the first variable is the answer to the question: is the current situation sustainable? A necessary process of judgement is made on *certain* criteria; the current 'as-is' system state—in any *certain* partiality or in its whole system state—is measured up against criteria of a conceptual 'ought-to-be' system state that an interest or advocacy envisions—i.e. a notion of how things ought to be, possible to be considered as an utopian ideal.

A crucial point to complicate matters is that we have to understand that the 'ought-to-be' ideal system state does not have to be shared between 'actors'—and can in fact be diametrically opposed to other actors' 'ought-to-be' ideal—as long as this divergence is not explicitly articulated, whilst still appearing as 'agreement' on the current state being unsustainable. In other words, looking at the same situation, multiple 'observers' can all agree that it is undesired, though for different reasons—thus creating merely a 'shallow' or illusionary agreement. Standing at crossroads where none of the actors want to be, they can agree on moving away from it, though in diametrically opposed directions.

Secondly; the current 'as-is' state of the system is deemed not-sustainable in its projected future (in)stability over a *certain* timeframe—where the timeframe of projections are a possible variable criteria as well. Simplified into the question: for how long can the current situation—if deemed sustainable—be sustained? This second variable is then integrally related to the degree of complete understanding and accounting of the system in question.

Yet, despite these variables possibly diverging wildly internally to a supposed agreement on the problem statement of sustainability—the current situation is not sustainable—an 'agreement' in the form of either a consensus or compromise outcome is still possible. For as long as the interests and advocacies agree that the current 'as-is' state, irrespective of what partiality they focus on, is not as 'ought-to-be', then sustainability is a problem statement that the current system state needs to be developed towards the 'ought-to-be' state, which the actors can agree on is at least not the current 'as-is'.

In short, diverging interests and advocacies look at the situation, the system state, and all agree it is not as they desire it to be—thus we have an all-round agreement and adoption of sustainability on the agenda. However, such ‘shallow’ agreement is of course not going to result in desirable results if the different actors ‘pull’ in different direction whilst continuing to chant their supposed agreement with each other. This, this author proposes, provides some understanding for why under the umbrella of the ‘sustainability’ agenda little change has been made, as has consistently been judged the case from the Earth Summits over the previous decades; the UNCED in 1992, the WDDS in 2002, and the UNCSD in 2012.

1.4.1 The bridge metaphor

The term ‘consensus’ is often used to describe the concept of sustainability (see Connelly 2007; Fergus and Rowney 2005; Waas et al. 2011; Fricker 1998; Christen and Schmidt 2012). The bridge framing generally denotes a consensus, bridging the divide between opposing interests and advocacies. It suggests that in the process that brought the concept of sustainability to the fore there was a markedly equal interest—and equal power relations in the process—in bridging the divide between conflicting interests. The metaphorical bridge between initially the economic interests and environmental advocacies is supposed to be built on a recognition of the opposing interest—and agreement upon a problem statement where both interests are threatened by instability of the system; i.e. agreement on the unsustainability of the current state. The ‘bridge’ or consensus concept stands as a landmark of remarkable political agreement between these, though its functionality and practical application are questionable.

The wide framing of the sustainability concept is then not accidental but rather a necessary, and perhaps even intentional compromise condition of the supposed negotiated consensus outcome. This framing allows for social actors of; the orthodox economic interests, environmental advocacies, and social welfare advocacies to operationalize their previously opposingly framed interests as non-confrontational towards a shared goal: sustainability—thus reframing, through sustainability, their relationships to each other as non-confrontational. The wide framing has facilitated the supposed consensus to become a nearly uncontested and universally acclaimed goal (see Appleton 2006; Meadows and Randers 2012).

1.4.1.1 Depth of consensus

Thus, a pertinent question that the consensus definition of political agreement poses is whether its concept of sustainability embodies any *real* agreement on what is to be sustained and how—relating to the variances in the previously discussed two variables of the problem statement on sustainability. In the case of relatively large variance in these; it would imply that only the words the previously framed competing actors use to describe their interests and advocacy have changed—whilst leaving the underlying oppositional framing intact and unresolved. The difference here is crucial and will be discussed here as pertaining to the 'depth' of the consensus on sustainability and SD.

A deep consensus for sustainability would mean that the agreement extends beyond merely acclaiming to desire sustainability—low variance in the two distinguished variables. A deep(er) consensus would be constituted by larger shared agreement on what ends sustainability pertains to—i.e. what is to be sustained and how to go about developing or maintaining an agreed upon (more) desired state of the system; relating to means.

Whereas a shallow consensus—a high variance in the two variables—would refer to a lack of agreement on what is to be sustained (ends) and/or how to achieve or develop towards, and/or maintaining the desirable state (means). A deep consensus on both ends and means—a low variance on *both* variables—would assert that the consensus definition can be more readily operationalized to increase the sustainability of the system. As in this case the actors involved will be working towards reconcilable goals and through reconcilable means.

The concept of sustainability as brought forwards by the Brundtland report (WCED 1987)—embodied and reified through the following Earth Summits—can be framed as a considerable political victory regardless of depth of the consensus. However, in the shallow waters of this political consensus the three dimensional model appears to have stranded the concept of sustainability. The diverging logics, a-hierarchy, claimed sovereignty, and independence of the dimensions makes these dimensions—diverging interests, advocacies, and related academic disciplines—appear as irreconcilable and at odds to each other as before the consensus was established. Thus regarding the depth of the consensus definition, this author argues it to pertain to a shallow consensus on both the ends—being poorly defined—and the means—as agnosticism towards validity, and defended by arguments of unstructured, paradoxical pluralism. While this has allowed the term its popularity and wide adoption, it can also be considered critically as the concept's weakest point. The wide and shallow consensus that has resulted in the abstract definition has created barriers to consistent operationalization as well as hindering critical assessment (see

Connelly 2007; Fergus and Rowney 2005; Waas et al. 2011; Fricker 1998; Christen and Schmidt 2012). The consensus definition therefore prohibits changing what is currently considered—paradoxically by this very consensus—as the unsustainable current system state, because the opposite; what is sustainable and the means towards it are not remotely agreed upon.

1.4.1.2 Consensus or compromise?

Dawe and Ryan (2003) note that it is certainly a positive development that the environment is 'considered alongside the economy and social wellbeing'. However, its inclusion and status as one of the three pillars or dimensions does not guarantee 'equal footing' with economics and social well-being. The same applies to the social dimensions and its explicit inclusion—after the insistence of civil society and developing countries in the 'South'.

In other words, the simple presentation and presupposition of equal importance—relating to the presentation of the dimensions as a-hierarchical—does not nullify prior and existing power relations; not just of interests but also of logic and rationales—for instance, between ecology and orthodox economics. This means that the presentation of sustainability as a consensus definition and a contested concept (see Connelly 2007; Söderbaum 2011; Söderbaum 2014) should not be uncritically accepted as such—as a consensus. After all, if the environmental awareness of the 1970s, and the following institutionalization process reminds us it posed a challenge to established neoclassical orthodox economics. The Limits to Growth (Meadows et al. 1972) was a challenge to the dominance of *economic* growth, likewise the Brundtland report (WCED 1987) can be argued to be (relatively) external criticism on dominant *economic* policies, practices and theories—and a call for more social and environmental considerations.

These prior power relations cast doubt on the presentation and claim of the institutionalized sustainability concept in its three dimensional representation being a consensus definition—i.e. mutual agreement between parties without significant power asymmetry. Rather, the supposed consensus definition might be more aptly described as one of a compromise outcome—'agreement' between parties where significant power imbalance is present.

If the consensus definition of sustainability is to be conceptualized as a 'bridge' between the divergent interests—constituted by the three pillar model as its supports—then this metaphorical bridge could be circumscribed by the following characteristics: The bridge stands as a monument to a great political victory, a formal ceasefire-treaty between conflicting and arguably mutually excluding interests, rationales, and epistemologies. The bridge represent a ceremonial construction to this 'agreement'—binding the conflicting parties to each other in formal language and validating each other's interests—even if these *appear still* irresolvable paradoxical. The monumental bridge itself providing a ceremonial path between them as reconciliation. However, the ceremonial bridge is built on shaky and unequal foundations as the discussion above has argued. As such, it is unable to fulfill its function as a bridge bringing people together across the banks of the river it is built over—lacking any functionality other than standing as a mere monument. Should any try to traverse it—as many keep trying to—the entire bridge stands at risk of collapse.

1.5 Salvaging sustainability and the double criterion principle

Thus, the bridging concept of sustainability is argued to be a compromise outcome of socio-political negotiations—a concept hiding socio-political, socio-economic, and academic disciplinary frictions. However, in a thesis on the relationship between sustainability and economics this leaves the question of how can the concept be 'salvaged'—for it to be made operational for the subject of this thesis; and academics and socio-political debates in general. As Christen and Schmidt (2012) state, the starting point to establishing a meta-framework for sustainability is to frame its formal character in the form of several questions or variables that the concept has to fulfill—as the previous discussion has already framed. This allows for comparisons of different and diverging operationalizations, and establishing criteria of validity; and in the measure of how explicit these variables, questions, and positioning are articulated in order to establish legitimacy of claims to power and how these relate to scientific validity or just representation of advocacy and interests. The choice is made here to construct a meta-framework in order to attempt to bypass—at this early point in the discussion—the hotly debated topic of *what* system state should replace, or is inherently more sustainable than the current system state (see Buch-Hansen 2014; Drews and Antal 2016; Ferguson 2016; Kallis and March 2014).

In order to firstly deconstruct sustainability and secondly (re)construct a meta-framework for sustainability, discourses and rhetoric of 'common sense', and 'taken for granted' logic and rationale have to be critically assessed—validity and legitimacy cannot be taken implicitly for this purpose, but require explicit articulation in relation to their supposed judgemental criteria (see chapter three; see also Rutzou 2016; Spash 2012b). For this purpose the discussion returns to the literal meaning of the verb 'to sustain'. Sustainability pertaining to a problem statement without a-priori content into the framing on *what* or *how* it is to be sustained is taken as providing a stable framework for this discussion—thus the start is the problem statement that an 'as-is' system state does not equal an 'ought-to-be' system state. To develop the conceptual meta-framework for sustainability further beyond the 'as-is' versus 'ought-to-be' system state judgement, two criterion are identified and suggested here: Firstly a normative criterion; i.e. the *desirable*, and secondly, a scientific criterion; i.e. the *possible.* Where the problem statement is judged through a *certain* actor their filling in of these conceptual criterions applied to an 'as-is' to 'ought-to-be' system state comparison.

This first question integral to sustainability is about what configuration of the state of the system or relations therein are *desired* to be (developed into and) sustained. What is (un)desired, what is (un)necessary, and what is (im)possible in the optimal conceptualization of the envisioned ends—or 'ought-to-be' system state—is constituted by their opposites. That is to say that the desired implies the undesired, the necessary implies the unnecessary, and the possible implies the impossible—in such simplified dichotomous framings. Using the term sustainability likewise implies its counterpart; unsustainability. Sustainability is then necessarily a problem statement—or lack thereof—on the basis of the two overarching themes; the (un)desired, and the (im)possible. The 'as-is' system state is judged to be either problematic and thus unsustainable, or unproblematic and thus sustainable. Sustainability is thus in the tradition of normative reasoning (see Knox-Hayes 2015) inseparable from *a certain* normative criterion as part of judgement; at least insofar as the system in question contains humans or relates in any measure to human activities or linkages.

The second criterion, and thus the second question is the framing of the *possible* is a question of 'means' to get to the desired 'ends'—i.e. the 'ought-to-be' system state. In other words, a question of what roads or paths lead towards the desired ends, and which would work against achieving these ends. This question relates to what ends or goals are envisioned by the usage of the concept of sustainability, by whom, and for whose benefit. Changing the system state, no matter the direction—or by whose judgement criteria it is more or less sustainable—is thus captured by the term of 'development' in this framework. Development, in this sense is continually made up, justified, and measured up against both normative and scientific criterion as well; as means towards *certain ends* (see Adkisson 2009; Kapp 1976). For illustrative purposes the described model is illustrated in figure 1 below (fig.1).

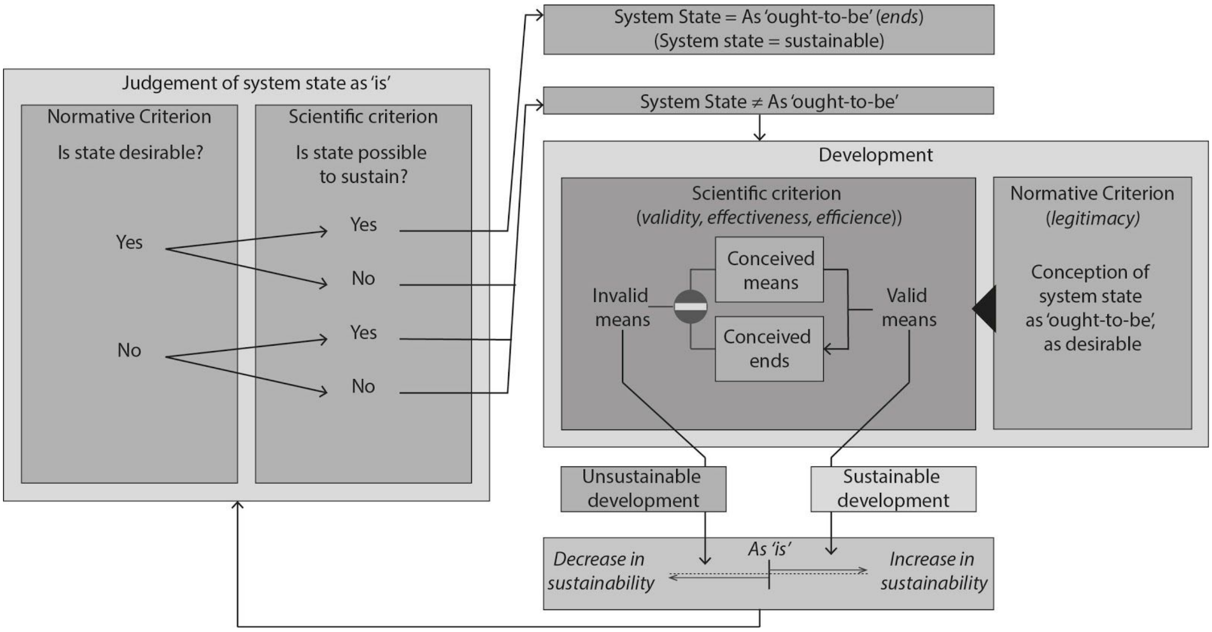

Figure 1. Conceptual problem statement model for sustainability.

The double criterion principle proposed here is deemed necessary to safeguard the normative relative nature of judgement on means and ends, and to safeguard the relatively objective scientific judgement—both being integral parts of sustainability in regard to anthropogenic economics. Both criterion are furthermore mutually constituted and have an interdependent relation to each other (see chapter three)—however, the normative is not reducible to the scientific, and vise-versa (see also Adkisson 2009; Kapp 1976; Kemp and Martens 2007; Rutzou 2016).

For instance: A current 'as-is' system state can in ideal-type theory be desired by all in it—therefore satisfying the normative criterion of sustainability as the 'as-is' equals the 'ought-to-be' according to the normative criterion. However, at the same time this desirable state can be impossible to sustain as judged by the scientific criterion—for instance, in a case of degradation of climatological and ecological relations in the system, overconsumption of a single or multiple resources or services in the system. Thereby the scientific criterion feeds back into the normative criterion—in the case of 'valid' awareness of crossing such thresholds in the absence of e.g. glaring ecological blindness (see chapter two). As the system's state will change due to its unsustainable consumption or transformations within it—i.e. degradation—normatively defined optimality relating to these changing scarcity patterns will have to adapt accordingly. Thus if the system is to be stable and to be 'sustained', then the normative criterion has to be adjusted to what the scientific criterion judges as the ‘possible’ state to be with its different thresholds than the current ‘as-is’ desired states.

The scientific criterion’s question that is to be answered and to be judged as (im)possible to sustain is likewise necessarily informed to varying degrees by the normative criterion. Do we ‘value’ satisfying global satisfaction of human needs—e.g. nutrition, hydration, shelter—and wants—e.g. correlating to high consumption patterns as for instance, average ‘developed’ countries material and energy consumption per capita? Or do we value satisfying these for merely for *certain* people—i.e. delineated by socio-cultural and ethnic, or socio-political lines such as ‘our’ country. The obvious question of whom the ‘we’ are that determine these to inform our scientific framing of the possible comes back up here relating to a socio-political spatial dimensions; as well does the question of a temporal dimension—to what time period this ‘we’ projects this stability to be important over?

Therefore, the scientific criterion in sustainability is partially constituted on the normative criterion in, for instance, the above discussed *choices* of system delineations that relatively objective measurements are to be made to frame the *possible means*. An ‘as-is’ system state can be judged as possible to sustain according to the scientific criterion, though not desirable according to the normative criterion. This system is likewise risking increased instability as the normative criterion is likely to drive development to alter the system configuration towards satisfying the normative criterion—in the process moving beyond what is possible to sustain.

It is appropriate here to emphasize that the scientific criterion is not a singular representation of agreement amongst disciplines—academic friction between disciplines is very much part of the reason for the compromised sustainability concept as has been institutionalized (Lehtonen 2004; Redclift 2005; Spash 2012a; Spash 2012b). In fact, this point is considered to be so important that the following three chapters will discuss in depth several of these frictions—between ecology and orthodox economics, social sciences and orthodox economics, and between thermodynamic implications for scarcity and orthodox economics. At this point in the discussion on sustainability and economics it should suffice merely to emphasize that despite all their internal divergences, a *certain* distinction is required in this author’s opinion between normative and scientific criterion to make sustainability operational.

A sustainable system state thus relies on both these criterion; on finding a state of the system that is characterised by (relative) equilibrium or stability of the system, whilst also being (relatively) desired (see also Christen and Schmidt 2012; Kemp and Martens 2007). A configuration guided dominantly by the normative criterion and in ignorance—willfully in atheism to it, or more innocently agnostic—towards a scientific criterion risks instability, as no amount of desire or construction nullifies the fact that a reality exists outside of our desire (see chapter three on ontological realism). Nor is a configuration guided solely by a scientific criterion—such as a technocratic or 'objectified' approach denies its own normative justifications—likely to simply nullify desires as indicated by the normative criterion.

1.5.1 The means towards ends and the ends of means

As previously discussed, the 'development' is framed here as *any* change in the 'as-is' system state; thus it concerns a means to ends relationship. The mutually constituting relationship between means and ends makes separating these from each other analytically challenging. However, it is a necessary exercise because separating means and ends from one another is important to combat reification that means are framed as ends—such as orthodox economic institutions, theories, and practices. This statement is more than mere semantics, as it can serve as a foundation for challenging taken for granted rationales, and rationalizations of already reified means. This analytical separation serves as a constant cautionary principle that although means can be taken as proxy indicators (metaphorical 'road signs') for 'progress', or lack thereof, towards desired ends, they are not the desired ends—the destination—in themselves.

A practical example of this can be found in the discussion on Gross Domestic Product (GDP) growth on the one hand, and 'wealth' and 'welfare' considerations on the other. Where GDP growth 'obsession' has taken a life of its own as *the* singular goal that orthodox economic theories, practices, and based upon policies focus on—even when more comprehensive measures of both 'wealth' and 'welfare', that GDP economic growth is argued to ultimately indicate for, are shown to decline (see Kallis 2009; Rees 2015; Van den Bergh 2011).

The relationship between the means and ends in this theoretical model of sustainability can be conceptualized as a criterion of judgement to which development—as altering the system's configuration and its constituent relationships—is envisioned, argued for, and legitimized by. Both require judgement on the double criterion principle for (un)desirability and (im)possibility. Sustainability thus call into focus the need for explicit examination and articulations on both what the destination is—the ends or the 'ought-to-be'—and what road to take to get closer to this destination. A destination without a road towards it is an unfeasible utopian fantasy, and a road without a direction or destination is an aimless contradiction.

1.6 Conclusion - The remodeling of the frame

The sustainability question (or variable) is argued in this chapter to be understood as a comparison between the 'as-is' system state, in relation to an 'ought-to-be' system state—a judgement on criteria that necessarily contain both a normative and a scientific criterion.

Through the institutionalization process these aspects have become more hidden and implicit to allow the concept of sustainability and SD to gain near-universal acceptance under the three dimensional model(s). To make the concept operationalizable (again), the frictions and paradoxical workings of the three dimensional conception need to be addressed, for which a meta-framework has been suggested.

In other words, the concept of sustainability can, and indeed has to be salvaged from its stranded position in the shallows of the wide political agreement that the concept is now founded upon—the paradoxical or contradictory relations between sustainability and orthodox economics have to be addressed beyond mere socio-political agreement.

An interdisciplinary approach is agreed on in the compromise framing of sustainability by the three dimensional model, however its supposed interdisciplinary character is where frictions remain. Thus in the next chapter the friction between the environmental and the economic supposed dimensions will be discussed in depth—with a particular focus on the academics frictions as manifested in the supposed sovereignty, and a-hierarchy as presented through the three dimensional approach to sustainability.

Chapter 2 Economics versus the Environment - A Paradox?

The economic and the environmental are presented in the three dimensional model as sovereign and independent 'spheres' or dimensions—governed by irreconcilable diverging logics, rationales, and interests. However, even in the compromise definition of sustainability it is acknowledged that obstacles to increasing sustainability lie in the linkages between the supposed dimensions—something that is better illustrated by the overlapping circles than by the pillar model. Crucially, having previously rejected the sovereign and a-hierarchy presuppositions of the three dimensional model of sustainability, these relations have to be explored and explicitly articulated for a workable sustainability model; functioning economics; and decreasing, halting, or reversing environmental degradation. The central theme of this chapter is thus how the environment and the economic relate to each other and how these linkages can best be characterized and made more sustainable.

2.1 The orthodoxy of economy and environment

It is foreshadowing to the direction of the following discussions in this chapter, and beyond, that both the academics of economics and ecology derive their etymology from the *same* source: the ancient greek word *Oikos*—roughly translating to a household or a family-unit. Thus 'eco-nomics' coming to mean the household *management*, and 'eco-logy' to the *logic* of the household. The legacy of this shared origin goes far beyond mere semantic similarity, though more on this in chapter three—first to frame the dominant orthodox economics' approach to the environment.

The Merriam-Webster dictionary defines economics as: "*A social science concerned chiefly with description and analysis of the production, distribution, and consumption of goods and services*" (Merriam-Webster 2018). This definition frames what the dominant orthodox schools of economics consider their field of study—'economies' as these are constituted primarily through actions of intra-human exchanges, and human-environment appropriation. The field is therein further delineated by constructions of *certain* socio-politically defined spatial borders—micro, meso, or macro scale; for instance, 'the economy' of countries—and temporal borders justified on a basis of analytical convenience, though generally considered as short term projection by other disciplines. The classification of orthodox economics as a 'social science' is a matter of debate; for although its field might pertain to intra-human (social) interactions, most of its methodology is unmistakably naturalist-positivist—controversially to many other social scientific disciplines.

The orthodox economic logic delineates economy then as a supposed self-evident *internal human economy* (i.e. anthropogenic), in which production, distribution, and consumption occurs—thus it frames the 'rest' as an a relatively *external environment*, containing resources or stocks that signify (primary) inputs and output sinks of resources or capital flows into the *human economy*. Production then in orthodox economic logic relies on this conceptual framing separating environment—as natural capital or resources—and economy—as manmade capital and labour. For the discussion here labour and manmade capital fall both into the category of human capital—i.e. what is framed as not-environmental or natural capital; as *internal* to the economy. To varying extents these framings indicate (and legitimize) what is considered important to account for within orthodox economics. What is 'internal' is relevant for considering (sub)optimal allocation patterns, and what is 'external' is (relatively) not, unless it crossed degradation threshold *perceived* to jeopardize the internal.

The external environment thus provides primary input—accounted for as natural capital—into the *human economy* system where it is transformed through processes denoted by 'production' (involving labour), and turned into manmade capital in the form of 'goods' and 'services'. These goods and services are distributed in processes denoted by 'provisioning', and finally again end up in the external environment once the capital or commodity has been 'consumed' to the point it is deemed 'waste', and no longer usable as a further input in the *human economy*.

Production here can mean a large variance of anthropogenic activity, for instance, including appropriation of 'unclaimed' or external natural capital through 'formal' value articulation. Due to the internal versus external—where only the internal is considered as value—these processes of appropriation are considered production as much as for instance, transforming iron ore into agricultural tools through extensive labor and energetic 'work'. Likewise, all of i.a. agriculture, horticulture, and forestry are considered to 'produce' products—that is to say that carrots being sold in a marketplace, and a log of timber transported from a logging yard are both be considered in the orthodox economic logic as manmade capital; irrespective of the 'transformation' or anthropogenic 'work' done on these. A wild carrot, being *external* natural capital, becomes *internal* once it is uprooted by a human, or its 'value' is considered and formally articulated in social relations, one way or another.

It serves to note here furthermore as well, that appropriation of unaccounted for 'manmade' capital within a *human economy* system—such as informal activity; the 'informal sector' or 'informal economy'—often through appropriation falls under the same framing in orthodox economics as 'production' once it becomes formally accounted for (see Van den Bergh and Kallis 2013). This is a crucial area of debate in relation to orthodox economics and other social sciences that focus on socio-economic development. A debate in fact, that has framed much of i.a. capitalism and marxism, and developmentalism versus post-colonialism (see Buch-Hansen 2014; Escobar 1995; Escobar 2015). However, these debates are not the central focus of this chapter, and beyond the scope of this thesis to do justice to. Briefly referring to these debates rather should highlight the inherently diffuse nature of the delineation between natural and manmade capital, and the problematic nature of holistically accounting for both. A degree of delineating between an *internal* and an *external* is arguably unavoidable—the crucial point is that these delineations should not be taken for granted, and are ever at risk of being reified from their relatively subjective delineations into objective inherently valid categories.

The notion of productivity in orthodox economics—of the *human economy* or anthropogenic economy (sub)system—lies in the evaluations, considerations, and awareness (i.e. perception) of inputs into the 'internal', against the outputs into the 'external'. The 'process of production'—irrespective of degree of transformation or merely appropriation—is firstly considered as productive in the degree that the output is more *desirable* than the inputs—in the eye of the beholder. Both as a process, that possibly needs to be repeated, and as an outcome. Awareness and valid accounting for inputs, processes, outputs, and system delineations are then crucial for how valid a claim to productivity is, in addition to the *desirability* of input versus output in the eye of the beholder.

Provisioning in orthodox economics concerns the (re)allocation or (re)distribution of goods, commodities, and services—crucially; according to a *certain* optimality distributive criterion (Wiesmeth 2012). In other words, provisioning concerns the *how* to get to an optimal allocation—an 'ought-to-be' system state. An optimal allocation pattern is by definition the raison d'être for economics in its broadest definition. Economics as theory and practice is a means towards satisfying a normatively informed optimality criterion—i.e. an 'ought-to-be' system state.

The purpose of this comparison with the discussion and meta-model of sustainability in chapter one is to emphasize that the goal of *all* economics is a *certain* notion of a desired and possible system state for *certain* interests and advocacies—i.e. social groups or individuals—through *certain means* considered as effective distribution processes; provisioning. In the orthodoxy framed by neoclassical economics an optimal allocation pattern is referred to as Pareto (sub)optimal—Pareto optimality being a state where no further (re)allocation improves the wellbeing or utility of the actors within the system, without diminishing wellbeing or utility of any other; a sort of socio-economic equilibrium (see Ferguson 2016; Wiesmeth 2012).

2.1.1 Informational deficits

The notion of *informational deficits* (see Wiesmeth 2012) is used to correct for the idea of a 'perfectly' informed economic actor in orthodox economic theories. A degree of *informational deficit* of economic actors, theories, and practices is highly influential in what is considered 'efficient' or 'productive', and relates closely with the conception of the Pareto-criterion. For example if an environmental resource is not perceived as scarce, then its optimal allocation in relation to the Pareto-criterion is likely to differ significantly as compared to its optimal allocation in a situation of high perceived scarcity.

When fishing stocks in the oceans were considered as inexhaustible the 'optimal' distribution—regardless of *how* to provision or reallocate for this—differed significantly as opposed to awareness of finite and degrading fishing stocks. In other words, it has significant influence on the processes of production and provisioning whether the allocation of a 'resource' concerns a situation of *perceived* limits due to scarcity—and can be considered a zero-sum-game—or whether it is perceived as a non-zero-sum-game based on *assumptions* of limitless or non-relevant limits for *direct* exploitation—for instance, due to scale of limits relating to influx of solar radiation into system Earth, or due to replenishment rates of fishing stocks.

As Wiesmeth (2012) notes, economic actors in a practical context are 'unlikely to possess complete or correct information' about commodities. *Informational deficits* are thus a theoretical concept functioning as a correction to the notion of the 'informed' economic actor. In this sense the concept attempts to account for short fallings in the concept of the 'rational' in decisions of the economic actors—without abandoning or significantly altering the pre-assumptive notions of the 'rational' economic actor. In the absence of 'correct' information the decisions can be argued to be internally rational—based on the (incomplete) information the actors hold—though externally judged as a degree of irrational; and so the outcomes accounted for as based on *informational deficits*. Thus, according to Wiesmeth (2012) this practical context of *informational deficits* requires introducing standards relating to exploitation—such as standards for air pollution and fishing quotas. It is here that environmental standards and orthodox economic goals compete for the same economic resources—as such environmental standards act as limits to economic exploitative activities, giving credence to the dichotomous oppositional framing of environment versus economy (Wiesmeth 2012).

The smaller the *informational deficits* are, and the more complete markets and pricing are, the less environmental externalities are argued to manifest in this framing. The more information that is available—through scientific understanding, and dissemination of this information to actors involved in an economic decision—the more accurate the price for e.g. air pollution will reflect the 'external' costs to the social world through environmental degradation. The question arises then why orthodox economics still adheres to this empty world economic logic of not recognizing the *physical scarcity* of natural capital. A possible answer that will be discussed in depth further on is that these *informational deficits* are inherent to the extremely rigid preanalytical frame of orthodox economic—i.e. its ontological presuppositions, epistemological claims, and methodological choices, that disallows for interdisciplinary cooperation with orthodox economic theories and practices (see Spash 2012b).

2.1.2 Completing the market

The diagnosis that orthodox economics thus generally makes in the face of environmental degradation is one of an incomplete market system—once confronted by decreasing flows of natural capital inputs or oversaturation of output sinks. Because of the incomplete markets and pricing the economic workings of the system are considered to be logically not functioning 'optimally' towards Pareto-optimal provisioning or distributions. Environmental economics—a branch of orthodox economics that acknowledges significant environmental degradation as a direct problem—positions itself as a correction to the associated environmental problems through such completion of markets and pricing. It rests on orthodox economic claims that a market system, in which the world is divided into tradable commodities is uncritically presented as the most efficient economic organization in relation towards a Pareto-criterion optimality distribution. Included in these taken for granted and generally implicit pre-assumptions of orthodox (environmental) economics is the belief that monetary commensurable value articulations can accurately articulate the value of a 'thing', and of the environment; such singular objectified exchange valuations and related narrow utility constructions are uncritically implied as unproblematic.

Environmental economics—as for instance, discussed in Wiesmeth (2012)—uncritically holds onto the notion that market economics itself is not the cause of environmental (and socio-economic) externalities and resulting environmental degradation—rather, the neoclassical economic practices are argued to not work effective enough (indicated by the externalities) because its logic is not applied thorough or complete enough; resting only to expand it further and more completely to allow flawless neoclassical economic logic to 'self-correct'. The environmental degradation that is occurring within the system is argued to be the result of improper or incomplete application of market economics, resulting in missing pricing and missing markets (Wiesmeth 2012).

Correcting for missing pricing, or even completely missing markets is done through attaching both a monetary 'cost' to degradation of the environment, and a beneficial price to 'services' that actors gain from this environment—only when markets are 'complete', unpriced externalities made internal through pricing them, and informational deficits reduced as much as possible is the neoclassical orthodox economic logic argued to work 'perfectly'. The word 'perfectly' is chosen here to represent the discourse of orthodox economics as it takes a dogmatic approach to criticisms against it—as pertaining not to flaws in its preanalytical frame, theories, practices, and institutions; but rather as pertaining by definition to faulty implementation and practice of the 'perfect' orthodox 'dogmas'. That is to say, orthodox economics tends to represent its theories as a-priori valid—articulating its theoretical understandings, and (perfectly executed) practices as pertaining to infallible natural laws—ontologically fixed. Thus implementation thereof failing indicates not a flaw in neoclassical orthodox economics, but rather in flawed application and practice.

Likewise through correcting for missing pricing and missing markets both *informational deficits* and environmental and socio-economic externalities are seen to be reduced, as these externalities are—in the now more ideal application of orthodox economics—now supposedly reflected through 'accurate' costs and benefits in these (new) markets; likewise 'informing' economic actors through these 'correct' prices. This approach is orthodox economics' response to environmental degradation, and to decrease of stocks and flows of natural capital that threaten orthodox economics' core focuses (see Wiesmeth 2012). Exploitation too close to such thresholds or crossing such thresholds means further degradation would become unaffordable—according to the economic logic relating to scarcity and the *limiting factor*.

Correct pricing of flows and stocks of natural capital is considered as to prevent their degradation beyond desirable thresholds; as rational economics actors would not knowingly exploit beyond thresholds risking increasing costs or decreasing benefits. Exploitation beyond such thresholds would mean the environmental stability and economic increase in productivity would compete for the same resources—where the latter is dependent on the former this would mean risking diminishing return on desirable flows—counter the rational economic actor's supposed drive for maximization of benefits, and minimization of cost.

2.2 A heterodoxy - Ecological economics

The notion of complete commensurability of all value—to make all things valued exchangeable once expressed in a unifying commensurable language of (e)valuation— is underpinned by orthodox economics' *supposed* positivist methodology. Crucial for the following chapter is that this ontological presupposition, epistemological claim and methodological choice in orthodox economics are generally considered so uncontroversial—despite recurring criticism from heterodox economic schools—that its analytical presuppositions (or pre-analytical framework) is rarely if ever explicitly articulated (see Daly 1992b; Daly 2015; Spash 2012a; 2012b).

One of the challenges towards the above discussed orthodox economics approach to the—supposed 'external'—environment comes from the school of ecological economics. Ecological economics' approach frames the environmental-economics relationship very different; as will be discussed here with the help of empty versus full world economics, ecosystem services as internalization, and ecological economics' call to (re-)embed the socio-economic dimension(s) *within* the environment dimension.

In the time when economics finds its origins as a formalized discipline the increase of *desired* flows—i.e. goods, services, and resources—relied on increasing the then *limiting factor* to 'economic growth'; manmade capital (Daly 1992b). For example; if growth or increase in the fish catch was desired it was primarily limited by manmade capital and labor—manmade capital such as fishing boats, nets, as well as knowledge in things such as location of fishing stocks and in methods for catching fish. Here the fish caught can be considered as the desired 'manmade' capital flow in the form of, for instance, food for direct or indirect consumption, or for exchange and thus income derived from trading in fish. The natural capital was generally not considered a *limiting factor* in inhibiting productivity increase; materials for e.g. fishing boats and nets—such as the wood to make the boats—could be imported locally scarce, and fishing nets be traded for or labor paid for through exchange. Furthermore, the fish stocks in the oceans were not *considered* or *perceived* to be scarce for much of modern history—as a whole that is; local scarcities and fluctuations being obviously *perceived* at times.

Thus, to increase productivity of the fish catch a focus on more or 'better' ships, nets, and labor was considered the economically logical investment. This increase in manmade capital would decrease the *limiting factor* to growth—an increase in manmade capital providing the catalyst for *desired* increase in the fish catch. The appropriation of natural capital, and its metabolization through and into manmade capital was considered as relatively ‘free’ of cost—offset against the *desired* increase in fish catch—in this relatively empty-world system state of the past due to *perceived* abundance-scarcity patterns.

Appropriation and decrease of stocks of natural capital—i.e. increasing its physical scarcity without perceiving a change in scarcity patterns; still being considered ‘abundant’—was thus seen as posing no threat to the value of manmade capital and its *desired* ‘growth’, other than the cost of initial appropriation or extraction (Daly 1992b). The latter being perceived as ‘paying for itself’ in their offsetting cost against the increase in fish catch—more food, or more *possible* income through exchange depending on ‘market’ demand and supply. In other words, transforming the system by decreasing *some* natural capital through for instance, cutting down more trees for boats, and catching more fish was *considered* or *perceived* as not risking the system’s desired stability. This empty-world productivity assumption became enshrined into (now neo)classical economics as it became a formalized discipline in practice and theory.

During the last two centuries as the orthodoxy of neoclassical economics became established, the global human population grew exponentially from one billion to over seven billion. With the logic that applied to the economics for production and provisioning of the first billion two centuries ago, the same empty-world logic is being applied and argued to work through orthodox economics for satisfying production and provisioning for the current over seven billion. Over the past two centuries manmade capital has accordingly increased with the population growth, and seen an increase per capita as well as aggregate ‘consumption’ levels increased. The scarcity patterns in the system have thus significantly altered—as increasing amounts of natural capital were metabolised in various ways into manmade capital.

For instance, increased fishing in both scale and intensity due to more manmade capital such as fishing ships, nets, labor, and increased ‘productivity’ of these, has increased pressure on remaining natural capital of fishing stocks—thus has led to decreased stocks, and reduced replenishment rates of existing stocks as the growth of direct pressure reached and crossed *certain* thresholds. Furthermore indirect or secondary effects of other manmade capital such as i.a. chemical and noise pollution in the oceans increased pressures and degradation as well.

With the shift of the human appropriation of the biosphere, and abiotic resources—indirectly solar radiation—from relatively low to relatively high (see Vitousek et al. 1986; MEA 2005) the limiting factor to production of desired goods and services in the form of *both* manmade and natural capital has also changed. The scarcity pattern of the world has made natural capital now the (generalized) *limiting factor* for increasing productivity—in variances per region, but significant shifts in system Earth can be identified. That being stated however, as manmade capital is crucially not equally distributed in both spatial terms—i.e. between countries—and in socio-political strata terms—i.e. wealth and welfare inequality within countries across system Earth—the 'need' for manmade capital is not as a whole satisfied despite the changed scarcity pattern and its implication for sustainability of the system state.

This shift has not gone unnoticed and has been challenged (see Meadows et al. 1979; Boulding 1966). However, the economic logic of the past system state and its *perceived* scarcity patterns are still firmly institutionalized and embodied—in orthodox economic theories, practices, and institutions. If the *limiting factor* in the current full(er)-world system state is natural capital, then the focus of economic policy should be on increasing the productivity and supply of natural capital—a shift towards conservation and regeneration of i.a. the biosphere (Costanza 2012; Daly 1992b). A focus on increasing productivity of manmade capital in this view is not just illogical, but counterproductive, in other words *uneconomical*. This point easily illustrated by returning to the analogy of the fish catch.

A decrease in fishing stocks, and/or a decrease in replenishment of fish stocks—regardless of whether it is as an effect from overfishing or 'natural' fluctuation—threatens the supply for the fish catch, and with it the desired flows of e.g. the fish, food, or income derived from trading in fish. The *limiting factor* to the fish catch cannot be bypassed let alone solved by increasing the fishing catch through increasing manmade capital such as more ships or application of different nets—e.g. dragnets. Such intensification inevitably will decrease rather than increase the productivity of the *limiting factor*; the natural capital—possibly increasing short-term catch, but over long(er) term by definition decreasing it. Economic logic and policy should rather focus on increasing the natural capital through sound ecological management of the fishing stocks and their 'environment'—by reducing secondary pressures such as noise and chemical pollution of the habitat of the fish. For instance, by lifting pressure off the stocks by decreasing flows through e.g. catch quotas, seasonal quotas, protecting spawning areas; and by facilitating healthy environments for the stocks to replenish in through environmental regulation.

In addition to the consideration of the *limiting factor* for 'economic growth', the variance between *perception of scarcity*; by those performing and deciding these 'economic' actions and policies, and *physical scarcity*—framed by scientific accounting such as ecological accounting and assessment (see MEA 2005)—is not adequately reflected in orthodox economics' approach to the environment. This variance results in a measure of judgement on of how validly scarcity patterns are accounted for and considered. In the case of ecological assessment versus the neoclassical orthodox economic rationale and scarcity *perception*—i.e. the empty-world economic logic—this can be referred to as a degree of ecological *informational deficit*, or *ecological blindness* (see Adams 2014; Spash 2008; Spash 2012a; 2012b)

2.2.2 The shifting commodity frontier

Thus the world has been argued to have shifted away from a system state relatively empty of manmade capital and full of natural capital—towards one that is relatively full of manmade capital but steadily depleting in its stocks of natural capital. Through this shift the delineations between the *internal human economy* and the *external environment* have continuously shifted as well. The *external* environment has become increasingly—selectively and in particular partialities—appropriated and 'internalized' through a shifting 'frontier' of attention and commodification from orthodox economics.

With it the coverage of orthodox economics' logic has expanded too—this shifting boundary referred to by i.a. Gómez-Baggethun and Ruiz-Pérez (2011) as the *commodity frontier.* As the frontier shifts in attempts to 'internalize' it, the environment is delineated into environmental commodities through what ecologically is deemed as partial measurements extricated from their contexts that give them 'value'—and arguably in many cases applies to partial anthropocentric utilitarian values for *certain* social groups or actors. In other words, a *certain* (e)valuation for *certain utilitarian* goals gains primacy and becomes reified as 'the value' of a thing (see Ellwood and Greenwood 2016; Martinez-Alier 2002).

Environmental resources and services that were previously accounted for by non-orthodox economic means—such as ecological and biological assessments, and socio-economic non-monetized value articulations—are reframed as environmental commodities through processes of monetization and commodification as the *commodity frontier* shifts to internalize them (Gómez-Baggethun and Ruiz-Pérez 2011; Wiesmeth 2012). Whether measured and monetized with the aim of being prepared for exploitation, exchange, or for the aim of preservation; the commodity frontier is generally one of conflict between competing and conflicting (e)valuation articulations—a frontier of conflict where the 'best of intentions' such as both conservation for anthropocentric goals, and socio-economic development for increasing 'wealth' or 'welfare' have both had the opposite effect through degradation of the ecology in question (see Adams 2014; Ellwood and Greenwood; 2016 Funtowicz and Ravetz 1994).

No translation is perfect, and as the proverbial saying goes much can get lost in the process of translation—none more so the case than between oppositionally framed disciplines such as ecology and economics. Conflicts at the commodity frontier often come to the surface through diverging value articulations between actors of divergent interests—corresponding to diverging intentions such as preservation of ecology, and exploitation and thus degradation. These conflicts are often easily identified as pertaining to markedly unequal power relations between the actors involved—be they socio-political actors or academic disciplinary conflicting assessments and (e)valuations. Such power relations are crucial for how the outcome as 'the' commensurable value of the *environmental commodity* in the formal *internal human economy* is constructed. Likewise the commodity frontier is the scene of many disciplinary battles between, for instance, ecology and orthodox economics, with markedly unequal power relations playing a considerable role in the outcome (e)valuations and policy advice. Orthodox economic logic seems at times to be in an unassailable position of power, as is clearly evidenced by the reflection of *its* logic of 'more of the same' under the name of sustainability in e.g. the outcome document of 'The Future We Want (UNCSD 2012) (see Bartelmus 2013).

In the economic logic of orthodox economics where the changed patterns of scarcity of the fuller system state are not recognized the shifting of the commodity frontier to increase commodification of the environment is framed as uncritically beneficial for the *human economy*—as rational means to increasing productivity. Commodification of the environment is thus considered to create new economic activity simply through uncritical increase of input, and opportunities for facilitating economic growth through 'creating' more value that has previously been external, and thus underutilized—i.e. suboptimally utilized by the *human economy.* Once internalized formally into the *human economy* this potential translates into more input towards desired 'producing' manmade capital and thus allowing for 'free' or 'untapped' productivity increase (Wiesmeth 2012)—making the orthodox economic internalization approach generally blind to the consequences of this further degradation through more direct and intensive exploitation.

2.2.3 The debate on complementarity versus substitutability

When changing scarcity patterns are 'recognized' by orthodox economics, such as in the case of environmental economics (see Wiesmeth 2012), one way the importance of the changed pattern of scarcity—decreased natural capital—is done away with is through the argument of *perfect substitutability*. This standard assumption of orthodox economics is that natural capital is *perfectly* substitutable as a factor of production by manmade capital. Such an assumption thus does not consider scarcity in natural capital as a *limiting factor* in production—as productivity can be maintained *perfectly* by substituting the now scarcer natural capital, for the now abundant manmade capital in production of desired goods and services. If the relationship between natural and manmade capital is described by *perfect* substitutability, than no economic shift to accompany a fuller world system state would be required, and likewise no change(s) required in the 'infallible' neoclassical orthodox economics theories, practices, and institutions, nor in its pre-analytical frame (see chapter three).

Daly (1992b) however, frames the assumption of *perfect* substitutability as a 'serious distortion of reality'—one that represents a persistent dogma within economics. If natural capital is *perfectly* substitutable by manmade capital then the reverse would hold true as well; natural capital would be a *perfect* substitute for manmade capital. This however presents a paradoxical reality as Daly (1992b) goes on to note: *perfect* substitutability of natural resources for manmade capital would remove any logical rational need for production and accumulation of manmade capital at all. Manmade capital such as for instance, a spear for fishing, a fishing rod, a fishing boat, a net—as well an input of human labor—are crucial for appropriating or 'producing' fish on larger scale. Manmade capital is not necessarily always—to the same extent and intensity—needed for appropriating natural resources; one can attempt catching a fish in a stream with their bare hands. However, with productivity defined as increasing output (fish) while reducing input (labor), it is as a rule not *perfectly* substitutable by natural capital.

Furthermore, what is argued to be a *perfect* substitute for natural resources, requires those resources for its own production—not to mention in the full(er)-world of socio-economic interrelations an infrastructure of both social and material relations. Manmade capital, both in terms of transformed materials external to the human biology (*exosomatic means*) and in terms of labor (*endosomatic means*), require natural capital for their production (see Daly 1992b; Georgescu-Roegen 1971).

To illustrate this point: The fishing boat is produced from, for instance, wood or metal that no human can conjure up from thin air—a point the discussion in chapter four on thermodynamics will expand upon as it is a very important aspect of economics—and although the latter is an a-biotic product of smelting, it too relies on a natural or abiotic inputs; that is to say *exosomatic means* as opposed to *endosomatic means*. Furthermore the obvious needs to be stated; the fishing boat itself is not going to deliver or magically spawn into existence the fish—without the natural capital of the fish, and a method and knowledge to catch them. The fishing boat, like the other manmade capital in this example 'complements' the natural capital of the fish by aiming to increase the 'productivity' of the catch; making it through ‘easier’ to catch the fish through *some* investment of other natural capital—transformed through some form of human labor.

Another obvious point should be stated here; that even labor is complementary—neither human labor; nor horsepower; nor electrically driven sources of mechanical movement work without input from natural resources along their product chain. Substitution of natural resources by manmade capital can *never* substitute the material resource inputs for production whilst manmade capital is itself produced from natural capital—inferring an argument so simple that unfortunately has to be explicitly stated: humans are biological beings *dependent* and constituted on their environment; we are by no means self-sufficient beings that ‘produce’ labor nor manmade capital *out of thin air*. A central paradox that is entirely engrained in orthodox economics; implied as well in the notion of technological decoupling, and the framing humans and the anthropogenic economy outside of our environment(s) (see also Daly 1992b; Dawe and Ryan 2003; Georgescu-Roegen 1971; Lehtonen 2004; Spash 2012b).

Although *perfect* substitutability is, as Daly (1992b) notes; ‘a serious distortion of reality’, a degree *certain* of ‘relational’ substitutability should not necessarily be excluded. As production can be reconfigured, a product redesigned, and a service reconstructed in a variety of ways to produce a difference in material and energy throughput though *similar* in its result—that is, it is possible to satisfy an adjusted demand with adjusted material and energy input. Such a decrease in input should however be critically assessed with a high degree of skepticism where manmade capital is to substitute natural resources in the production process. For as discussed above, manmade capital cannot be taken as a perfect substitute for natural resources, let alone should such substitution be taken as an increase in efficiency a-priori analysis or evaluation; in other words it should not be taken for granted and uncritically taken as desirable under the notion of technological efficiency or orthodox economic productivity increase.

In a dichotomous framing of manmade and natural capital as the factors of production—i.e. a system framing of an internal *human economy* and an external stock of natural resources—the two factors of production are fundamentally complementary to each other and the economic logic of *perfect* substitutability is rejected as an inherent contradiction. It is argued here to present a fallacy of decoupling that undermines economic theories and practices that built upon these notions—to which *perception* of changing scarcity patterns will catch up sooner or later with likely undesirable economic consequences. What is needed to maintain a degree of productivity of production—let alone considering increasing productivity as framed by the manmade-natural capital framing—is shifting investment towards improving the stocks and flows of natural capital.

2.2.4 Investing in natural capital

From the supply side, investment in natural capital entails accounting for the natural capital—using ecological and environmental assessments—to determine under which conditions its stocks can increase (i.e. restoration), or remain stable (i.e. preservation or conservation), as well as corresponding thresholds to the flows that can be appropriated by the humans *as part of their environment and ecology* (see Costanza 2012; Gendron 2014). Beyond these thresholds environmental degradation occurs; meaning a decrease of the productivity of anthropogenic economic structures possible that uses the natural capital. Such degradation can entail a decrease to the rate of replenishment of the stocks of the natural capital, meaning appropriation of flows by the *human economy* is to be limited—e.g. fishing quotas, season quotas for fishing. Beyond further thresholds of degradation however, entirely cutting off human appropriation of these specific flows from the natural capital becomes necessary (i.e. conservation). Beyond such a threshold investing in the natural capital is either done through conservation—i.e. allowing the stocks to replenish—or active attempts at restoring the stocks and environmental stability, which generally requires extensive human capital investment.

Referring back to the issues of complementarity as noted by Daly (1992b) it follows logically here that demand from the *human economy* and economic logic are merely secondary in determining the 'cost' of the investment—as the natural capital in question can only *limitedly* be substituted by manmade capital to artificially keep supply of the desired flow up by substitution to satisfy demand—if at all possible; for instance, extinctions of species are rather final. Though demand informs the framing such of ecological and environmental assessments in setting what the desired flows are that the assessments are measured against, the necessary investment to provide these flows are dictated by ecological and environmental identified conditions—i.e. the scarcity of natural capital, regardless of 'economic cost' that the investment requires.

Increasing the productivity of restoration; (re)growth of natural resource stocks requires—either directly, or indirectly through manmade capital or omission of exploitation—input of more natural resources. Thus often meaning further *decreasing* human appropriation in sum total within the system, in addition to relieving the 'stock' in question—in other words, an 'economic' cost or investment that is significantly probable to be greater than *not crossing* such ecological thresholds to degradation. Here the *limited* substitutability refers to—directly or indirectly in the form of manmade capital—inputting natural capital that is less desirable into restoring the natural capital that is desirable. However, such inputs though not consciously framed as desirable natural capital flows can still have negative (degrading) effects on ecosystems that frame in turn other natural capital which are framed as desirable flows—thus incurring further economic costs to the necessary investment into the natural capital. Here obviously the concept of *informational deficits* and *ecological blindness* are highly relevant.

A logically following subject is then the cost and pricing of such investments. Having discussed the complementary relationship between natural and manmade capital—and how economic logic would dictate a shift towards investing in natural capital due to the changed pattern of scarcity in a much fuller world—the question remains whether merely shifting the investment towards natural capital, and adjusting economics its visions to acknowledge changed patterns of scarcity would suffice for stabilizing or restoring natural capital—and thus would result into an alignment of economic logic with 'environmental' reality. The 'costs' or pricings of such investments in natural capital, and the pricing of natural capital as services and resources are the subject of accounting for ecosystem services.

2.3 Assessing and internalizing the environment - Ecosystem services

The concept of ecosystem services was initially conceived to emphasize a dependence of social and economic constructions on ecosystems—utilitarian relations that the concept of ecosystem services aimed to highlight as often undervalued or even unvalued in orthodox economic articulations and markets (Adams 2014; Armsworth et al. 2007; Gómez-Baggethun et al. 2010; Peterson et al. 2010). This framing of this relationship as 'ecosystem services' was initially an attempt by ecologists to *internalize* the environment into the language and considerations of orthodox economics to highlight the importance of conservation—thus as a pedagogical concept.

The concept served to highlight that many environmental 'services' and 'environmental commodities' that characterise human 'economic' actions *within* their environment had often been overlooked in accounting and decision-making informed by orthodox economics. Economic valuations of ecosystems—where they were employed for this purpose—served more as illustrative purposes within academic debates and for raising public awareness, than as reliable monetary articulation of economic value and ecological dependencies (Fisher et al. 2009; Funtowicz and Ravetz 1994; Gómez-Baggethun et al. 2010; Kronenberg and Hubacek 2016; Peterson et al. 2010).

Identified ecological relationships are judged through ecological assessments and understanding in relation to orthodox economic accounting—i.e. what is important to account for— (e)valuations—how important what is accounted for is. Articulations of their value are juxtaposed against ecological assessments and socio-economic dependencies of and on *certain* human-ecological relations within this ecological framing to arrive at an assessment of orthodox economic under-, un-, or overvaluations of these relations. The criteria for how under-, un-, or overvalued ecosystem services are in orthodox economic articulations are framed in terms of the dependencies of the (desired) provisioning upon the specific ecosystem services, and the general ecosystem stability these relate to. The concept of ecosystem services can thus be considered as highlighting and challenging a '*too-narrow'* conception of utilitarianism as articulated through orthodox economic (e)valuations of its environment (Adams 2014; see also Funtowicz and Ravetz 1994; Spash 2012a).

The concept of ecosystem services should thus not be considered as a call for intrinsic valuation of nature—nor as a challenge to the principle of a utilitarian relation. Rather, the concept of ecosystem services was proposed by ecologists in order to form an internal challenge to orthodox economic theory and practice—i.e. within the language of utilitarianism and orthodox economics. The concept of ecosystem services served to move the constructed relationship between economics and environment away from one of dichotomous opposition between them, and towards one of unidirectional dependence, mutual influence, and of crucially a hierarchical relation instead of one of sovereignty and a-hierarchy—the conceptual socio-economic dimension as existing *within*, dependent on, and bound to the borders of its environment.

For the concept to be integrated within the economics, the value of these services needed to be articulated into discrete units of commensurable value. The ecological assessments of the ecosystem, the 'services' gained from them—in relation to desire towards satisfying a Pareto-optimal allocation pattern—are then to be 'translated' from contextually dependent, interconnected 'services' into discrete decontextualized commodities expressed in monetary values. A process of turning diffuse 'services' that only in their relations exist having to be made into discrete decontextualized units. These articulated monetary values nevertheless aim to reflect the costs and benefits associated with current states of ecosystems in order to *conserve their contextual whole*—hoping to highlight the costs are inherently greater if the system is (further) degraded.

After the publication of the Millennium Ecosystem Assessment in 2005 (MEA 2005) the economic articulation of the value of ecosystems gained increased attention in policy and economics (Fisher et al. 2009), often as opportunities were seen in the ecosystem services for moving the commodity frontier and thus increasing growth through internalizing externalities. Paradoxically then, the concept of ecosystem services, though intended as a pedagogical tool aiming to *stabilizing and conserving* ecosystems, instead inadvertently facilitated further exploitation—*decreasing stability* of the ecosystems further through expansion of the *commodity frontier* once the concept was appropriated by orthodox economics (Spash 2008; Gómez-Baggethun et al. 2010; Gómez-Baggethun and Ruiz-Pérez 2011; Peterson et al. 2010).

Being unpriced does not relate (inherently) that the 'part' can readily be extracted; i.e. moved within the system away from its current context, or degraded within the system, without an effect on the system or its stability. That a certain 'part' of an ecosystem such as an animal or plant species, or a regulatory process, is not formally by orthodox economics valued does not mean it has no effects within an ecosystem—ultimately influencing the *human economy* (Costanza et al. 2013; Gómez-Baggethun and Ruiz-Pérez 2011). For instance, as Spash (2008: 264) illustrates: "*The 'total value' in economic terms of, say, oxygen is the value human's* [sic] *place on their own survival. That fresh air lacks a price does not mean it has no value* [..]" In other words, there is a conceptual distance between orthodox economic-utilitarian articulation of value of ecosystems, and identified ecological-utilitarian articulation of 'value' or importance of ecosystems—ecological blindness of the neoclassical orthodox economics.

Orthodox economic appears to take a rather agnostic approach to the fact that such costs and benefits derived from ecosystem services and environmental commodities influence actors already before articulated formally into the market economic system. The resources and services derived from environments are already part of the system, in which the *human economy* with all its external connections exists—and as the discussion above has argued is embedded upon. Which in a relatively full world system, where natural resources are the limiting factor in the pattern of scarcity (see Costanza 2012; Daly 1992b; Daly 2015), often means a zero-sum-game. Such ecosystem services or environmental commodities already being part of (a) production and provisioning organization for (certain) social actors in the system there is no 'free' commodification or degradation. Altering the stocks and flows of such resources and services through marketization can thus have a degrading effect on them, on the system stability, and thus on the already formally accounted for part of orthodox economics' framing of economy.

2.3.1 Antimorphic and dialectical clashes

One barrier to effective translation of ecosystem services and other system relations into orthodox economics is how the former concern relational and dialectical characteristics of the system; incompatible with the discrete, self-contained, and decontextualized approach of discrete commodities and resources with antimorphic characteristics (see Georgescu-Roegen 1971). Ecosystems as a concept refers to system constructions with *dialectical* characteristics; "[..] *a concept with overlapping, interactive and diffuse borders.*" (Gómez-Baggethun and Ruiz-Pérez 2011: 621-622). The borders of these constructions are diffuse for the purpose of emphasizing *relations* in situ; logical continuity, interconnectedness, dependencies, mutual constitutions, overlapping constructions are the name of the game for dialectical system foci. Thus the difficulty of separating such (eco)systems, relations therein, and how its parts such as species of flora and fauna relate to each other to form the ecosystem make it inherently resistant to discrete separation or decontextualization of its 'parts'.

Though dissecting an elephant might result in separating it into discrete 'parts', the animal will result in the animal's death in the process. For, although the animal's organs, muscles, and bones are very much its constituting parts forming together the elephant, 'separating' these from each other through dissection takes away the *specific* relations in a *specific* combinations between that forms an alive elephant—it is not *just* the parts of the elephant that constitute its body, let alone an alive-and-well elephant; it is the context and relations between them—the same applies to a dialectical system from of 'ecological services' and socio-economic dependencies on them.

Thus, as Adams (2014) notes that in ecosystems different services are co-produced, can interact synergistically, or may compete against other services. The state of an ecosystem in its totality, as well as in its 'services' that the *human economy* benefits or derives negatives from, is influenced by the presence or absence of 'parts' within it—independently of whether such 'parts' are (e)valued or *perceived* by the social and the economic (see also Spash 2008; Lehtonen 2004; Kallis et al. 2013).

The orthodox economic framing of the environment as divisible into sets of environmental commodities*,* and the 'translated' concept of ecosystem services framing of ecosystems pertain to a antimorphic framing where the emphasis lies on self-contained parts that can readily be taken out of any context and moved to another context. Ecosystems are turned into discrete, distinct and mutually exclusive parts of, for instance, 'capital', 'resources', 'services', or 'functions'. This framing focuses on a *certain* utilitarian relationship between *certain* actors in the *human economy* of the system—this discrete framing is inherently *partial* and thus likely to be beneficial only for *certain* actors.

As the concept of ecosystems is translated to the language of orthodox economics, it thus loses the contextualized foundation as part of a system, and gains antimorphic characteristics; “[..] *a concept with discrete and well-defined limits*.” (Gómez-Baggethun and Ruiz-Pérez 2011: 621-622) as a decontextualized part on itself. That this framing bears an uncanny resemblance to the three dimensional model of sustainability—its supposed sovereign, independent, and a-hierarchical; in other words, non-relational to each other—is not coincidental; orthodox economic logic and interests bore their hegemonic discourse in the framing of that sustainability modelling.

The dialectical nature of ecosystems thus accounts for the *uncooperative nature* of internalization of the environment into orthodox economics (Kallis et al. 2013; Vatn and Bromley 1994)—an epistemological clash between orthodox economics and ecological accounting for the environment of a system; and its constituent parts and relations (see Spash 2012a). The attempts of orthodox economics at internalizing the environment—as advocated by environmental economics (see Wiesmeth 2012)—can thus be framed as inherently involving *complexity blinding* of the environment. The ‘environment’ made into antimorphic commodities and services being contradictory to the very notion of system relations that constitute the i.a. ecology of the environment within which the anthropogenic economy is embedded (see Gómez-Baggethun and Ruiz-Pérez 2011). Such an approach of internalization into orthodox economic itself constituting theoretical conceptual degradation—not surprisingly then that once implemented, degradation of the actual ‘physical’ environment tends to follow in the footsteps of this conceptual degradation.

The identification, categorization, measurement, and monetization of a constituent ‘parts’ of an ecosystem sets up these constituent ‘parts’ for exchange as antimorphic entities in the orthodox economics’ reified construction of the *human economy*—with its supposed invalid decoupling from the environment and natural capital framing. Concepts such as ecosystem services, natural capital, and environmental commodities, are thus not ‘neutral’ in application, but rather have too often framed the environment for further commodification and transformation—risking (further) decreased stability, i.e. degradation (see Gómez-Baggethun and Ruiz-Pérez 2011; Kallis et al. 2013).

2.4 Conclusion - Re-embedding economics back into the environment

The environment and the field of economics as economy in its external, sovereign, and a-hierarchically framing to the environment has been discussed and forthright rejected in this discussion. As Dawe and Ryan (2003: 1459) rightfully state in referring to the three 'legged' sustainability model: "*Simply put, humanity can have neither an economy nor social well-being without the environment. Thus, the environment is not and cannot be a leg of the sustainable development stool."* In other words, orthodox economics and the three dimensional sustainability model represent an invalid system understanding and delineations therein. A paradox not *in* the relations between orthodox economics and the environment, but rather a contradiction *of* neoclassical orthodox economics to reality; and the *human economy* its embeddedness within it. This contradiction is the result of orthodox economics' *ecological blindness,* and its invalid system framings—leading to economic theories, practices, and institutions that ultimately degrade their own foundation(s) in acting on this invalid understanding and framing of an impoverished reality.

Instead, a clear hierarchy argued for by ecological economists that frames the *human economy* by definition *within* and dependent upon its environment(s) has been argued for as a necessary condition for *any* long(er) term functional economics towards a system state that is non-degrading for anthropocentric goals within system Earth in a full(er) world context—i.e. high world population, and high consumption levels related. The construction of the economy as a field sovereign and independent from *its* environment(s) is thus judged to be a contradictory understanding of reality, relating to questionable epistemological claims and inefficient methodological choices for restructuring the economies.

Orthodox economics appears however incapable of the above discussed required 'internalizing' *its* environment(s) to correct for its invalid and therefore inefficient; uneconomic system framing and system restructuring—as many ecological economists have pointed out (see Daly 1992b; Spash 2012a). Orthodox economics fails to effectively 'correct' for undesired or stability-jeopardizing environmental degradation. That is of course not to say that *no* improvement is possible through these approaches—ecosystem services approaches for instance, *can* deliver desirable results. However, for halting let alone reversing environmental system degradation more significant change and harmonization of economic organization and our environment is required (see also Costanza 2012)—theories and practices of economics contradictory to a (physical-environmental) reality simply cannot be expected to effectively deliver a prospect of increasing sustainability in environmental terms *for* anthropocentric socio-economic goals.

Chapter 3 Interdisciplinary Sustainability Economics - A Tautology

In chapter one the character of the consensus or compromise conception of sustainability was discussed and its supposed interdisciplinary approach rejected—due to its framing of interactions being between sovereign and a-hierarchical dimensions. Chapter two has discussed and illustrated these suppositions of an 'external' environment, and concluded that these have to be reframed instead as hierarchically structured—the socio-economic means and goals being embedded within the environment of a valid closed or isolated system or economy framing. Thus an important premise that this discussion is based on is that economic theories, practices, and institutions *are* social theories, social practices, and social institutions; socially constructed and justified by these constructions.

At the end of chapter one the proposed meta-framework for sustainability argued that an interdisciplinary approach to sustainability is in essence a tautology—if done 'correctly'. The following discussion will attempt to frame a philosophy of science to allows for a more interdisciplinary economics correspondingly, without on the one hand assuming an a-priori external environment, while and on the other hand avoiding an approach of an a-priori environmental determinism and reductionism dictating economics and socio-economic goals and means entirely.

The following discussion its point of departure is discussing diverging philosophies of science in positivism and subjectivism ideal-types, within a system theory understanding—in order to understand what character(istics) a philosophy of science for an interdisciplinary approach to sustainability and economics as a *means-ends* relation will have to take on in the light of rejecting the supposed sovereign and a-hierarchical three dimensional framing—i.e. mono or multi disciplinary approaches. In chapter four the discussed and proposed meta-framework for (more) interdisciplinary economics is expanded upon by returning to critically questioning delineations of economies by neoclassical orthodox economics.

3.1 On elephants and the blind, and falling trees in the forest

> It was six men of Indostan to learning much inclined, who went to see the Elephant (though all of them were blind), that each by observation might satisfy his mind. The First approached the Elephant, and happening to fall against his broad and sturdy side, at once began to bawl: 'God bless me!—but the Elephant is very like a wall!' The Second, feeling of the tusk, cried: 'Ho!—what have we here so very round and smooth and sharp? to me 't is mighty clear this wonder of an Elephant is very like a

> spear!’ The Third approached the animal, and happening to take the squirming trunk within his hands, thus boldly up and spake: ‘I see,’ quoth he, ‘the Elephant is very like a snake!’ The Fourth reached out his eager hand, and felt about the knee. ‘What most this wondrous beast is like is mighty plain,’ quoth he; ‘'t is clear enough the Elephant is very like a tree!’ The Fifth, who chanced to touch the ear, said: ‘E'en the blindest man can tell what this resembles most; deny the fact who can, this marvel of an Elephant is very like a fan!’ The Sixth no sooner had begun about the beast to grope, than, seizing on the swinging tail that fell within his scope, ‘I see,’ quoth he, ‘the Elephant is very like a rope!’ And so these men of Indostan disputed loud and long, each in his own opinion exceeding stiff and strong, Though each was partly in the right, and all were in the wrong! So, oft in theologic wars the disputants, I ween, rail on in utter ignorance of what each other mean, and prate about an Elephant not one of them has seen! (Saxe 2017 [1872]).

As this parable originating from India and formalized by John Saxe in 1872 (Saxe 2017) goes, so too do many different observations and claims to what economy ‘is’—and how it should be accounted for—exist by virtue of experiencing, accounting for, and advocating different partials of ‘system Earth’s economy’. As previously discussed this partiality goes beyond just the socio-political debate of diverging interests and advocacies and the normative criterion of sustainability. The debate runs deep between and within scientific disciplines as academic debates (see Daly 2015; Dawe and Ryan 2003; Lehtonen 2004; Spash 2012a).

The metaphor of the elephant is then an useful illustrative point of departure to discuss an epistemological framework for an interdisciplinary approach to economy—the elephant being an analogy for ‘reality’; ontology, and the blind men analogous for scientific disciplines and human knowledge and fact construction in general; epistemologies. In an attempt to move the debate for sustainability and economics beyond the pillars supporting an uncritical socio-political compromise-based sustainability operationalization, and likewise to move beyond rigid disciplinary boundaries as sovereign and independent disjuncted accounts of the economy of a system—if not paradoxical or contradictory. In other words, to move beyond the paradoxical or contradictory claims to what the elephant is, and what it is not.

3.1.1 A philosophy of science for system economics

The parable of the elephant is a useful thought experiment to illustrate how different disciplines—with diverging ontological presuppositions, epistemologies, and methodologies—can be framed to operate in relation to one another, whilst accounting for the same system its economy. These divergences are similar in their partiality of what is examined by the blind men—in other words, the field, subject, and context of disciplines being these partialities, akin to the elephant's body part examined by each blind man. These different approaches to different partials of the whole can have the result of different and diverging extrapolations of the partial to the whole; leading to paradoxical or contradictory representations of reality (see also Schellnhuber, Frieler, and Kabat 2014).

Through accepting a premise of ontological realism—that disciplines examine the same external-to-human-construction reality; i.e. the same elephant—is one that absolute positivism would find hard to internalize as it requires acknowledgement of fallible relativism, and that absolute relativism would find hard to internalize due there being an reality that our constructions are part of instead of constructions 'making' reality. Thus, a premise not without its implicit opposition.

One could hardly fault those who do not know what an elephant is, and without the senses to observe or construct the whole—due to epistemological and methodological limitations related to our inherent human physiological constitutions—to draw conclusions from the partial to whole; such as for instance, the German forester in the 18th century considering the financial worth of a tree to be the actual tree. To be clear here; *all* of us humans are *by definition* limited to knowing partialities in this regard, blind men and women all; none of us has seen, or will ever see the elephant in its whole or 'know' reality in its entirety. Granted, the metaphor of the elephant is perhaps not the most apt for illustrating this point—as many humans have seen either an image of an elephant, or even one with their own eyes in the wild or in a zoo.

Looking for a metaphor to illustrate a whole of reality, that we by definition cannot describe, and struggle to 'comprehend'—easily indicated by considering past scientific paradigm shifts and fallibility of previously considered valid epistemologies as well—is an obvious paradox on its own. Perhaps it is then best illustrated in the famous science-fiction works by Douglas Adams titled 'The Hitchhiker's Guide to the Galaxy' (Adams 2017 [1979]); where the answer to 'the answer to life, the universe, and everything' is determined to be rather unsatisfactory and simply: '42'. A reference to a fictional work indeed, but it is illustrative for the point that beyond 'gross' abstractions such as 'reality', analogies of an 'elephant' whose totality we are blind towards, '42', or metaphysical claims, we simply cannot describe or know the whole. Describing or accounting for the whole arguably requires such inherent 'gross' simplifications and categorizations; through which we construct what we consider the whole such as the 'elephant' to be—the three dimensional modeling of the reality for sustainability within system Earth is one of these.

Humans are regardless of our scientific achievements and our philosophical treatises still biophysically constituted beings; limited by our neural networks within our brains to 'comprehend' and constructed or account for the whole of reality—furthermore by definition parts of, and within systems such as system Earth. Thus, to 'know' the whole of all parts, relations, on every analytical level—without 'gross' simplifications, such as '42'—is an impossibility. Thus, our constructions will always be that, theories, assumptions, measurements, models, etc. of reality—not reality itself.

Thus, applied to the parable of the elephant this means no external observer knows the whole; all men are blind, and ignorant of what an elephant is in its whole as the metaphorical analogy to an entirety of a system. Any 'observation' to experience the elephant involves a-priori selection and context construction; across disciplines what the field, context, or subject is considered to be, and what methods are most valid to account for it. Thus a separation between between what is observable by a human actor and can be articulated as a 'fact' is hard to validate, as Caldwell (1980) noted in relation to a philosophy of science for economics—instead the epistemologies of disciplines are dependent on ontological presuppositions; if explicitly stated, or ontological assumptions; if implicit, and *not* explicitly stated.

A further illustration to this principle: The blind man having experienced a tree before compares his experience of the elephant in a pre-analytical framework of what a tree is, and in comparison with 'experiencing' the elephant's knee concludes it is similar enough to be a tree. This blind man's prior epistemological constructions on how to account for reality—i.e. knowledge and theory—leads him to conclude the knee of the elephant—or extrapolating this to the elephant as a whole—is in fact a tree. As Spash (2012a), notes, objectivity of science so too can be challenged; as subjectivity and a degree of subjectivism is impossible to nullify; even in the most positivist structured experiment.

In relation to what an economy 'is', this subjectivism in combination with social and materially manifested power differentials mean that we should be highly critical and skeptical to dominant rigid conception of what is 'internal' and 'external' to an economy. For, as Knox-Hayes (2015) notes; articulations within what we consider the scientific paradigm—and as articulated through 'valid' scientific language—are constructions with relations to social values, and are moderated through social value informed evaluations. Neoclassical orthodox economics' claim to being detached from normative and subjective constructions cannot be taken at face value merely by its supposed 'valid' positivist language and methodology—rather, we have to consider that (e)valuations articulated through orthodox economic theories, practices, and institutions pertain to *certain* interests of *certain* actors or groups being reified as objectively 'the value' or utility of a 'thing' (see also Spash 2012a).

3.1.2 The view from within a tunnel

In Scott's (1998) seminal work 'Seeing Like a State' he presented the danger of relying on positivist methodology alone. Scott argued that *certain* forms of knowledge and fact construction risk (over)simplifying reality, in their attempts to make reality more legible—for *certain* actors and *certain* purposes. Scott referred to this degree of reductionism as 'tunnel vision' of *certain* ideas of utilitarianism that aim to make the subject more legible for *certain means*, purposes, and interests. This *certain* utilitarianism—objectified as *the* utility—then often too becomes reified as 'self-evident'.

For instance, in Scott's example of German 18th century forestry the tree its 'worth' became solely the economic exchange value or use value for the actor in-situ of its timber. Scott's example of German forestry is apt here to the discussion of what an economy 'is', and for reconstructing an epistemology to account for it. The trees of the German 18th century forests were conceptually reduced from trees as i.a. biological 'parts', and their part in ecological relations within a system to the simplified and reduced reality of the 'fiscal tree'—devoid of its position or context in relation to, and dependencies on i.a. ecological, climatological relations, and social relations of the *actual* in-situ tree. This representation of the 'fiscal tree' posed serious problems for 18th century German forestry if the 'fiscal tree' became seen to represent or substitute the 'real thing' (see Scott 1998; Wiersum 1995).

Working upon assumptions of this 'fiscal tree' being an adequately accurate representation for the utility of timber production, the concept of the fiscal tree became reified. Confusing an epistemological representation, such as the fiscal tree, with the properties and characteristics of an actual tree—in situ with i.a. Its ecological and climatological relations—is something that in the philosophy of science can be judged as an epistemological fallacy; confusing epistemology with ontology (see Archer et al. 2016; Rutzou 2016).

The concept of *reification danger* is then apt here; as the simplified reality makes the 'real world' more legible for a *certain* purpose. Through its disjunction from what it is, this simplification for a *certain* purpose can gain primacy over what it is actually simplifying—in other words, the simplified reality or *proxy-indicator(s)* becomes considered as the *actual* ‘real world’, instead of being a *particular* and *partial* representation, measurement, and focus for *certain* purposes. Scott’s (1998) case of the german forestry can be taken as an example of the same problems that the ecosystem services approach has presented, once ‘internalized’ or taken over by orthodox economics.

As previously discussed this process was accompanied by claims of *certain*—i.e. partial or ‘narrow’—socio-economic utilitarianism. This utilitarianism brings with it risks of *reification danger,* through this narrow utilitarianism, of the power relations informing what is considered as ‘utility’ and efficient use—i.e. exploitation and degradation versus conservation—in a given situation. The ontology of parts in situ, in other words in their context and relations of the *system’s economy*, thus require a degree of relativism and pluralism towards what anthropocentric utilitarianism entails—what ‘use’ in terms of costs and benefits these are to various individuals or groups of humans in system Earth across micro, meso, and macro scales.

Furthermore, any claim to value-neutrality and objectivism as informing the narrowing ‘tunnel vision’ should not be uncritically taken for granted. Processes of ‘narrowing down’ is done from a *certain* position; informed by *certain* positional conceptions of i.a. rationality, efficiency, productivity, and utility. In other words, the ‘utility’ of for instance, a tree—and thus how to (e)valuate and articulate its ‘worth’, and what ‘work’ upon the tree is ‘efficient and effective’—is dependent (i.e. *relative to*) the positioning of the actor(s), their criteria for judging, and their selection of relevant context, *and* physical understanding of the tree—i.a. ecological, biological, and physical understanding of the tree, and its position within relations within the system.

For illustration of this point: a carpenter might look at a tree and ‘see’ the wood of the tree in terms of the hardness on the Janka hardness scale, and he or she might see in the shape of the tree and its branches what it could be used for. A lumberjack might look at the same tree and ‘see’ whether at its current age is the right time to cut it down. A climate scientist might look at the tree and see it as a carbon deposit; and either a future carbon sink or ‘carbon bomb’ if cut down. These examples framing the utility of a relatively discrete tree relating to cutting it down—i.e. *certain* ‘work’ upon it being efficient for the tree to be of utility. On the other hand however, an ecologist might not even ‘see’ the tree in itself as much, but rather focus on the ecological relations that the tree is part of, for instance, the tree its effect on water retention of the soil, its shading of the forest floor creating *certain* forest habitats. A hiker or tourist might similarly focus beyond the single tree its utility, but ‘see’ the forest of trees their utility and value by their aesthetics and ‘natural’ appeal. Both these latter examples focussing on the tree its utility *within* a larger system that is harder, if not impossible to extract from their contextual system and relations.

To be clear about this point however, in all these examples framing the tree its utility, as both a discrete resource or commodity, and as a relational part in a larger system, risk reductionism—acting upon the tree through cutting it down, or not cutting it down *both* can have simultaneous utility. In other words, *certain means* relate to *certain ends*—*only* in these relations does utility and value exist. These relations can be actively hidden or made implicit through processes of normalization into reified concepts (see Sayer 2015), however 'rationality', 'efficiency', 'productivity', and 'utility' are inherently positional or value-subjective. This point is easily demonstrated by persistently asking; 'why?', 'for what purpose?', and 'for whose purpose?'—answers to these questions need not be devalued simply because of their inevitable and inherent normative constructions. As Knox-Hayes (2015) and Sayer (2015), *all* economics is moral economics, especially in a full(er) world context where environmental cost-shifting is not longer possible (see also Carrier 2018; Daly 1992a; Martínez-Alier 2012; Myrdal 1978).

The discussion on ecosystem services in chapter two, and Scott's (1998) example of the fiscal tree in forestry illustrate how *certain* actors their valuations become reified—i.e. normalized—as the 'worth' of a service, commodity, capital; or for example ecological part of the system (see also Funtowicz and Ravetz 1994). 'Positivist measurement' is not independent of subjectivism and normativity, but framed by selection, delineation, considerations of relevance on what to measure or represent—i.e. epistemological claims and methodological choices that often contain (implicit) normalized or objectified *subjective* positions on what is valuable, and of use. Thus, implementation of such inherently *partial* (re)presentation of the 'real world' are not nearly as separable from subjective positions as neoclassical orthodox economics and positivism presents it to be—the former its supposed starting point free of normative overtones or 'is versus ought-to-be' comparisons (see also Spash 2012a).

Accounting for economy—i.e. the metaphorical elephant—is however not served by uncritical epistemological relativism either; an argument that all reality is completely relative to the observer, as postmodernist schools of relativism tend to imply (cf. Funtowicz and Ravetz 1994). Such forms of absolute epistemological relativism applied to a model for sustainability and economics would create a paradox of their own, nullifying validity in accounting for economy, as well nullifying a distinction between a philosophy of science and metaphysics. In other words, it would leave no analytical space for critically judging competing and contradictory accounts for efficiency towards sustainability.

We know from Scott's (1998) example that the fiscal tree representation of a tree in the real world was impoverished representation compared to our understanding the biological and ecologically situated tree and forest in question—a point that German foresters in the 18th century were forcefully reminded off when the fiscal tree representation was put into practice through (re)organizing timber plantations. In its reified monoculture of solely the reified 'financial tree' forest or plantation system, it resulted in costly-to-correct ecological collapse (see Scott 1998; Wiersum 1995). The impoverished financial tree monoculture was too ecologically 'blind'; in other words too reductionist towards the *physical 'actual' tree*—thus decreasing profits and rising costs to maintain the forest system more artificially; i.e. uneconomic restructuring of the system.

As Escobar (1995: 130) acknowledged in his seminal work on development: "[..] *Representations are not a reflection of 'reality' but constitutive of it. There is no materiality that is not mediated by discourse, as there is no discourse that is unrelated to materialities."* A point that cannot be overstated; our representation of reality—and utility and value therein—*is* constructed; however, it is a construction by 'real' biophysically constituted human beings, and furthermore *about* something 'real'—our theories, practices, and institutions of economics are constructed, however the *system's economy* exists 'outside' of constructions as well.

The challenge then is to 'unify' both positivism and this subjectivism approaches to economy within one framework—in constructing a philosophy of science for economics to account for and restructure the system's economy 'efficiently' towards sustainability. In other words to reframe them from either talking past each other completely—under notions of sovereign and independent aspects or dimensions—or being paradoxical up to contradictory to each other.

3.1.3 Unstructured pluralism and commensurability

Sufficiently wide pluralism of methods and theories is possible through starting from a strong social constructivist position for an interdisciplinary framework for economy. However, as Spash (2012a) argues; a strong social constructivist position in interdisciplinary approaches is often marked by unstructured pluralism, whilst the preceding discussion has shown that on the sustainability and economics relation *critical judgement* on pluralism is required to move beyond paradoxical or contradictory accounts of both current, and for developing the system its economy. This is due that the fallibility of all epistemology is acknowledged by a position of absolute epistemological relativism—extrapolating this fallibility of human epistemology to be a characteristic of ontology however can be considered as an epistemic fallacy (see Spencer 2017).

For instance, all accounts and conclusions to what the elephant 'is' are framed as *inherently and indisputably* equally valid articulations of reality under absolute epistemological relativism—or rather that none of them *can be valid articulations of 'external' reality*. Thus absolute epistemological relativism is more about representing different points of view and rather agnostic or even atheist about how these views relate to a 'truth', or validity in accounting for ontology. An unstructured pluralism position towards epistemology and methodology in relation to ontology implies an 'anything goes' in extreme towards what accounts should be incorporated into an interdisciplinary framing (see Dow 2007; Spash 2012a). A caricature of absolute epistemological relativism, that few actually adopt. However, the caricature is framed here to illustrate that critical judgement—on explicit criteria—for what approaches to economics, and how the conflicting framings of economy—e.g. The three dimensional sustainability model—can be resolved.

Such a position should be careful through the process of uncritical pluralism to not nullify considerations of that crucial immaterial relation of power between humans, as reflected in our 'knowledge' construction and hegemony. Equating all methodology and epistemology as absolutely constructivist, subjective, or relative, on a basis of ontological agnosticism or even atheism can be argued to be contradictory to its own basis of epistemological relativism. An a-priori position of uncritical and unstructured pluralism on the field of economics for instance, provides no space for judging what theories, practices, and advocacies are effective or efficient, or simply conflict with e.g. ecological partially 'external' reality to human construction—only facilitating for 'equal' advocacy of both orthodox and heterodox schools of economics, which is clearly contradictory (see chapter two). In ignorance of validity criteria on this supposed 'equal' field of ideas, the power relations between different constructions will make a casualty out of science, validity, and challenges to dominant taken for granted discourses—such as neoclassical orthodox economics.

An a-priori position of absolute epistemological relativism, and ontological agnosticism or atheism for economics is considered as undesirable here for the purpose of this thesis, and economics in general in agreement with Dow (2007) and Spash (2012a)—without abandoning social relativism altogether. A presupposition of ontological realism is thus argued to be necessary for an interdisciplinary approach to economics and sustainability.

Ontological realism here simply means a presupposition that a reality exists and is 'real'—irrespective of our claims to epistemological ability to conceive, account, or construct for it ‘objectively’ or *only* relatively. The task then in accounting for economy—outside of the narrow field of the neoclassical orthodox economic delineations—to acknowledge *certain* incommensurability. Thus to balance between unstructured pluralism and singular epistemologies—likewise rejecting supposed single-level ontology-epistemology relations where all ‘knowledge’ or ‘facts’ are supposed to be translated into *one* completely valid or natural language—for instance, arithmomorphism: epistemological claims to the validity of expressing all of reality through quantification alone (see Georgescu-Roegen 1971).

To return to the Indian parable and Saxe’s poem on the blind men and the elephant briefly: In the thought experiment the blind men conclude about the *whole* through interacting with different *partials* of the elephant—in other words, their conclusions on the ‘elephant’ are epistemological claims about ontology, made through different epistemological delineations; context, field, or subject delineations, and methodological choices. The blind men can be argued to represent each different disciplines in assessing different *partialities* of the *whole*. A ‘whole’ that is connected, and in fact, the elephant does not exist without its constituting *partials.*

Here the uncritical pluralism position would mean the elephant is simultaneously a wall, a spear, a snake, a tree, a fan, and a rope, and anything else that any blind men would think it to be, would mean his or hers construction *would be actual* reality; ontology—an epistemic fallacy. Absence of experiencing any part of the elephant by a single actor would made the whole affair even more paradoxical, akin to Schrodinger's cat (see Schrödinger 1935 translated in: Trimmer 1980; Brown and Fehige 2017) as the elephant its ‘being’—i.e. ontology—takes on another superposition; now both existing and not existing in any of its wall, spear, snake, tree, fan or rope forms. Should in the opposite instead an a-priori positivist extreme position be taken towards the elephant; one based on ontological realism, and complete knowability and commensurability of ‘knowledge’ and ‘facts’ then the result can be caricatured as only one of the blind men’s conclusions being ‘true’ and valid, and the others’ simply being entirely wrong—a belittling impoverishment of reality that something surely the elephant would have something to say about should it be treated as a tree and cut down, treated as a snake to be milked for its venom, or its tail considered a rope and tied into knot.

3.1.4 The forest and the falling trees

To discuss epistemology for *system economics* further, the discussion will first need to position itself more clearly on ontological presuppositions; starting with that of ontological realism. For illustrative purposes the thought experiment of a falling tree is used here: If a tree falls in within a forest, does the tree hitting the ground make a sound if no-one is around to hear it fall?

An absolute (epistemological) relativist approach would problematize this notion by answering that the question is altogether wrong. Framing the relationship as one of hermeneutics at best; our ability to account for reality only through our constructions, meaning all of reality is principally constructed or differently framed that because we cannot 'know' anything except through our constructions—up to this point this author agrees with—leading up to the idea that we cannot *know* there exists anything other than our constructions. Epistemology being all that we *know* exists, implying thus in extreme that only our construct or thoughts can be studied, and have to be understood as separate from 'what is real'—a problematic position towards economics for human beings with biologically 'real' needs within a finite and ever full(er) system context. The question of the falling tree making a sound would thus be invalidated entirely by such a presupposition of ontological atheism or agnosticism.

From this position the question of the falling tree making a sound without an actor to construct—i.e. 'hear', 'experience', 'observe'—the sound is framed as a non-sequitur, i.e. a logical fallacy. Without an actor constructing the reality of the falling tree hitting the ground this reality is either non-existent, or simply impossible to argue for because a construct of sound cannot exist independently without an actor constructing such a notion—a presupposition of ontological atheism or agnosticism respectively. Patterns identified or constructed through epistemologies are then not properties of an external 'reality', but rather *entirely* properties of the epistemologies and the actors constructing these themselves. From here it can be a short step to confuse epistemology with ontology. To consider thoughts—as individual or social constructs—as the only subject of study, without understanding that these are thoughts and constructs *about something* external to an individual or multiple social actors makes critical pluralism impossible as no external criteria would exist to judge upon.

The field and subject of social sciences in general is distinguished by relativism as an epistemological basis—accompanied by various degrees of ontological realism, atheism and agnosticism—thus concerning more the ideas or thoughts about 'reality', than it does accounting for the actual 'reality' (Archer et al. 2016; Blunden 2009; Moses and Knutsen 2012; Spencer 2017). The reverse can be said for an approach that is dominated by an positivist approach—where the non-quantifiable social world is at best treated 'agnostically', and at worst actively denied existence altogether beyond its quantification; i.e.

commensurability into arithmomorphic language (see Moses and Knutsen 2012; Georgescu-Roegen 1972; Scott 1998).

Such an ontological presupposition—ontological agnosticism or atheism—is problematic in an approach to economy. As argued previously; an accounting for system relations and parts—that anthropogenic activity and anthropocentric goals of optimal distribution depend on—requires acknowledgement of the non-anthropogenic parts and relations of the system as being relatively independent of our constructions of these. The parts and relations being not reducible to anthropogenic activity or constructions *alone* means simply not constructing them does not reduce the *system's economy* down to the impoverished notion of it within the construction.

To illustrate this argument by returning to the metaphor of the elephant: Without a construction by the blind men *of* the elephant in its entirety, or of parts of it, the elephant would not be denied its ability to trample the blind men if enraged by their inquiries to its existence. The metaphor of the elephant might be stretching at this point, however in similar fashion to this illustration; the *system's economy* of system Earth likewise can 'trample' human existence and our economic reconstructive desires towards the system. This is in fact not so much a hypothesis as it is already occurring in, for instance, changing climates, ocean acidification, air pollution, and ecological overshoot (see MEA 2005; Meadows and Randers 2012), as our accounting and understanding of these system relations is catching up to reality—though unreflected in the neoclassical orthodoxy of economics.

In similar fashion; *not* constructing a notion of human beings' basic biological needs such as water and nutrition (a construction of epistemology) does not negate the biological ontological reality of these—the actor constructing such a notion would find it hard to stave off death through starvation or dehydration simply by wishing it away or trying to not construct epistemological understanding for these. Though we cannot 'know' reality except through our inherently incomplete and subjective constructions—epistemologies with varying fallibility towards ontology—we simply cannot construct our own reality at will (Archer et al. 2016; Rees 2015; Rutzou 2016; Spash 2012a; Spash 2012b Spencer 2017; Tacconi 1998).

To sum up the ontological presuppositions that this author argues are necessary in accounting for economy, for restructuring the system its economy towards our desires and possibility to sustain this state: Reality exists without our constructions of it, where the reverse does not hold true—our constructions are constructions *of something* (though variably fallible), and are not independent of reality but constituted within it. Thus an explicit presupposition of ontological reality; the falling tree in forest making a sound when it hits the ground even if no human hears, measures, or observes the waves of sound resulting from the fall, is argued as necessary here for economics. Economics as our theoretical constructions, and practices—and institutions built upon these—has to follow the 'external' reality of i.a. our own biophysical, and the system its ecological and climatological environmental relations, not the other way around—convincing the elephant that it is in fact a tree or a rope is simply not an option.

3.2 Herding kittens - A multi-leveled ontology and structured critical pluralism

The field and subject of social sciences as thoughts and social constructs of reality as internal to the observer, and positivist sciences its field and subjects as reified regularities argued to be external to the observer, are then distinctly different from each other. These differences however are argued to not be of just the epistemological claims, but as pertaining to ontologically different entities. Both the fields of study—i.e. context, subject, or field delineation—being different *partialities* of reality—in other words, examinations of different body parts of the elephant, and accounting for *partiality* aspects of the same subjects through different epistemologies and methodologies—in other words different methods applied to the same body part of the elephant. Crucially then, both being within the same ontological realism as previously argued for.

Thus a single level ontology is rejected here as Spash (2012a) similarly rejects a single level ontology for ecological economics; a singular expression or language of valid articulation of reality is considered contradictory to what we can discern of reality through pluralistic approaches. The emphasis on disciplinary differences is then not just on grounds of diverging and competing epistemological claims, nor on just ontological assumptions or presuppositions—rather, the different analytical levels of the multi-leveled ontology are framed under a ontological presupposition here as disjunctive epistemic logic *about* a conjunctive ontology; which we cannot 'know' as a whole, appears to us as a disjuncted multi-leveled ontology—which crucially cannot be contradictory, but only might *appear* so (thus paradoxical). Creating a frankenstein's monster by stitching together a rope, a wall, a snake, a tree etc. does not create an 'elephant'.

Epistemologies as pertaining to different partials of ontology can thus be structured to one another to form a larger picture of the multi-leveled ontology—i.e. the system as a *whole*. Structure here crucially does not imply a-priori importance of disciplines or analytical levels. Referring back to Dow's (2007) argument for the need of incommensurability; the structuring argued for is one of structured epistemology and methodology, as accounting for different partials of the multi-leveled ontology in a framing of ontological realism. This multi-leveled ontology of structured epistemological pluralism is borrowed here from the philosophical school of critical realism (see Archer 2016; Spash 2012a; Spash 2012b; Spencer 2017).

The ontology constituting the conjunctive whole of the system, the disjunctive multi-leveled aspect of ontology then lies in the epistemological fragmentation (see Kagan 2010)—in other words, our understanding of ontology; of the system, is unavoidably partial by virtue of our epistemic: The previously acknowledged fallibility of all 'knowledge', 'facts', as well as due to the value-laden nature of facts, and the fact-laden nature of values (see Archer et al. 2016; Rutzou 2016).

3.2.1 The matryoshka doll of structured epistemological pluralism

As Spencer (2017) notes, thoughts as the subject of social sciences exist not in a vacuum but exist by virtue of social; i.e. intersubjective situations. For instance, a simplified example: We can position the field of social sciences as pertaining to an ontologically different field—of social constructs or thoughts—as a 'higher' level of analysis, structurally related to the field of the ontologically different biological disciplinary field; in this sense the latter being a 'lower' level of analysis. All thought and social constructions are manifested in, and foundationally constituted by neural connections in the human brain(s) of the actor's; within the biological bodies of human beings—thoughts, culture, alike all 'social' or individual constructions cannot exist without this neural, and biophysical foundation—eschewing and rejection *metaphysical* notions of thought existing outside of a human body.

Likewise our biophysical bodies are embedded and dependent on relations of ecology—we require a certain environment made up out of other biological organisms; for food for instance, and for regulating atmospheric content of oxygen. In turn, these ecological relations are embedded within the physical level of analysis, for which our understanding of it is governed by for instance, chemistry and molecular physics. The crucial note has to quickly be made here that the terms 'lower' and 'higher' levels of analysis pertain to embeddedness; but do not denote 'a-priori' importance, and are contra-reducibility and have to be understood in terms of a degree of incommensurability. Epistemological irreducibility of levels of analysis is an integral notion of this presupposition of embeddedness, as these epistemological levels of analysis pertain to different ontological partials or levels.

Here then the importance to accounting for the economy of a system lies in how this framing allows for surpassing the false oppositional framing the three pillar dimension of sustainability—its supposed sovereign and a-hierarchical characteristics, that facilitate the perpetual continuation of pre-existing frictions, and power differentials legitimized under supposed 'scientific' validity of diverging dimensions logic. The classical orthodox field of economics pertains to a social system, and as such is constitutionally embedded within it (Adkisson 2009). The reverse can not be said; not all of social relations are embedded or constituted by the classical orthodox framing of economy (Rees 2015; Spash 2012a; 2012b). The social, in turn is embedded within the bioecological, as previously argued for through both the inescapable biological nature of the human body; its biological needs, and as well through highlighting humans are part of the 'environment' of system including its ecological relations.

These picked levels of analysis for the example above are of course not exhaustive, nor necessarily exclusive. Rather, discussing the social, biological, ecological, and physical serves as illustrative to the argued for embeddedness. Thus, to reiterate again the necessity for *all* economic theory and practice to be aware of its system's environment—be that for what it considers 'social externalities' or 'environmental externalities'—i.a. ecological relations. The point to this whole discussion on elephants, trees, and economy. This framework allows for what Dow (2007) called for; structured pluralism, as opposed to unstructured pluralism.

3.2.2 Critical pluralism and judgemental rationality

Framing a *structure of pluralism* is then the next task for a philosophy of science framework for sustainability and economy. In other words *how* to frame the diverging and competing accounts *within* the plurality of epistemologies is to be judged; i.e. structured and contradictions arbitrated for. Adopting a form of critical realism allows for a position between extremes of epistemological relativism, and singular positivism—thus recognizing that although all 'knowledge' is fallible, not all 'knowledge' is equally fallible. The 'critical' in critical realism serves by its adherents as a term to distinguish itself against what is considered as 'naive realism' (see Archer et al. 2016; Rutzou 2016; spash 2012a; Spencer 2017). Taking epistemological claims of reality for granted—for instance, through not explicitly stating or acknowledging ontological assumptions of an epistemology—results in simplistic accounts or naive accounts of realism (Rutzou 2016). This 'naive realism' accusation—for an accusation is what it is for instance, towards orthodox economics (see Spash 2012a)—is comparative to Scott's (1998) framing of the fiscal tree as an impoverished version of the *real* tree.

Critical realism is summed up by Archer et al. (2016) as a reflexive philosophical stance aiming to provide an informed frame of (the philosophy of) science. It involves awareness of social constructivism, and its lessons that knowledge is context dependent thus always constructed, historically situated, and relating to social power relations. However, critical realism also embraces ontological realism; thus accepting reality as existing independent of humans, prior to human construction, and in the absence of social constructions of it. Though ontology is still unknowable in its entirety, marking methods of fallibility as insufficient ‘evidence’ for ‘truth’ of knowledge due to the previous discussed teleological and reification effect of constructions.

Thus, there are no ‘truth values or criteria of rationality’ that are independent or external of social constructions—of epistemologies. Critical realists argue that epistemologies are always relational as *historically situated* accounts, from a *certain* perspective. All accounts of knowledge are then principally fallible (see Blunden 2009; Funtowicz and Ravetz 1994; Knox-Hayes 2015), though not all constructions of reality give the same explanatory understanding—thus, not all knowledge is ‘equally fallible’ (Rutzou 2016).

This position of critical realism applied to economy and economics, and sustainability frames it at odds with post-normal approaches to economics (see Funtowicz and Ravetz 1994). For post-normal science approaches to economics the emphasis lies on representation of actors, negotiated outcome of ‘truth’ and knowledge; thus avoiding evaluations of what articulation is ‘right’ or ‘wrong’ (Funtowicz and Ravetz 1994). This approach is argued, by Funtowicz and Ravetz (1994) for instance, to allow for better recognition of conflicting interests and power relations that in ‘normal-science’ allows for hegemonic paradigms of ‘truth’ or ‘right’.

The benefits of taking a ‘post-normal’ scientific paradigm position are not dismissed here; Funtowicz and Ravetz (1994) their call for pluralism of methodology is embraced, adding to Dow’s (2007) emphasis to resist unitary commensurability. In particular post-normal scientific positions can give methodological advantage in discussing value and (e)valuations—as pertaining to the normative criterion of sustainability—and allow analytical safeguards against reified value articulations as informed by *particular* hegemonic rationalities and *particular* hegemonic utilitarian notions (see also Ellwood and Greenwood 2016).

However, as previously argued, the characteristic of absolute relativism is judged here as lacking in usefulness for accounting for the *system’s economy*. A post-normal approach its strength in allowing plurality is simultaneously its weakness for critical assessment. Sustainability in the meta-framework (see chapter one) is about normative criterion *in relation* to a scientific criterion within a system—understanding ‘utopian’ or ‘good life’ constructions is valuable to framing the normative criterion without doubt, however as previously discussed; such destinations that no road can lead us towards are unfeasible fantasies. Furthermore, an ‘anything goes’ pluralism is paradoxical in assuming an ‘equal’ playing in inherently not allowing for understanding of power differentials, thus also allowing or facilitating elite capture—reinforcing or further exaggerating power differentials.

For an interdisciplinary character in sustainability and accounting for economy across the positivism-relativism line there is simply no escaping the fact that 'the social' in all its constructions exists within an ontology that is made up of more than merely 'the social' constructions—not outside of it or constitutive of it this ontology. Accepting a degree of ontological realism is necessary for accounting for and effectively altering a *system's economy* towards sustainability. This thus poses limitations to a plurality notion of 'truth'—necessitating judging a 'right' and 'wrong' of articulations of it. Lest validity is thrown out of the window entirely in favor of the 'anything goes' approach—which is not to diminish relativism its authority in accounting and describing social constructions, merely that it alone is not enough.

Pluralism of epistemologies and methodology should thus not only adhere to a structured embeddedness of the multi-level ontological presupposition; but should also be critical towards accounts and articulations of 'knowledge' about ontology—where the frictions in the sustainability three dimensional compromise lie. Thus claims of epistemologies to pertain to ontologically different field or subjects or partials thereof; the foundational aspect to epistemic variances are not exempt from critical assessment. Instead of neutrality or absolute relativism of truth and knowledge, the *relationality* of truth and knowledge is argued—relational to temporal or historical contexts, and spatial contexts—i.e. between social actors, and between system constructions and delineations.

As Spash (2012a) notes, methodological pluralists face a paradoxical situation if they would operate uncritically in favor of supposed absolute 'neutral' relativism. For any concept of knowledge or meaning requires selection, delineation, judgement, and evaluation—criteria for rejection or inclusion. Such criteria, as well as facts and knowledge are not completely neutral or objective objects, but the result of knowledge production and power relations; As Rutzou (2016) notes: "[..] *Facts are theory laden, theory is value laden and values are paradigmatic rather than given. In other words, there is no neutral position with which to view the world or assess theory."* Within critical realism this concern of how to judge or evaluate criteria for critical pluralism can be denoted by the term of cautious ethical naturalism (Rutzou 2016). Evaluative judgement are thus not opposites to objectivity, but rather the two are mutually interdependent (Sayer 2015).

In other words, all knowledge is fallible, facts are value-laden claims to truth, and values are facts-laden as well (Rutzou 2016). Yet, selection criteria for evaluation are required to judge between competing accounts for a philosophy of science to separate itself from pure metaphysics of absolute epistemological relativism.

Any selection or delineation involves judgement or evaluation criteria, it is just by definition a matter of whether these are stated explicitly, implied, or (intentionally) hidden. In the case of orthodox economics Spash (2012a) argues strongly it concerns implicit criteria. Judgemental rationality then serves as an acknowledgement that such judgement or evaluation cannot—and should not be avoided—lest it will be hidden beyond supposed 'neutrality' that serves to reinforce, legitimize, or strengthening power imbalances; as orthodox economics does (see also Söderbaum 2015).

Thus judgemental rationalism is simply a rejection of the supposed 'neutrality' of the judgemental relativism that absolute epistemological relativism would favor—where little to no evaluation would be possible (Archer et al. 2016; Rutzou 2016). Critical realism for sustainability and economy frames the ontological presuppositions of ontological realism, and the epistemological claims of critical and structured pluralism as a philosophy of science for this endeavour.

The complexities of macro reality being made up ontologically out of combinations of matter-energy, are epistemologically incommensurate to a sum of its parts. The philosophical paradox that this presents; having to acknowledge both the structured multi-leveled ontology and ontological realism, though seemingly only inherently accountable to humans through epistemological and methodological pluralism, does not negate the importance of recognizing the structured embeddedness of one, and the irreducibility of the other. 'Reality' exists outside of and prior of our constructions of it; the tree falling in the forest without an observer nearby still makes a sound as it falls and collides with the forest ground. Furthermore reality does not have to abide by human ambition—such as socio-economic desires. By no means is the ambition of developing towards 'ought-to-be' system states, and maintaining these assured success if the scientific criterion is implicitly ignored—i.e. agnosticism—or explicitly denied—i.e. atheism.

3.3 Conclusion - The elusive economy

Being blind men all, we cannot learn the elephant as a whole—partiality and a degree of subjectivity are inherent to human epistemology—with an unavoidable degree of fallibility therein through the spatial and historical relationality of truth and knowledge. We cannot learn the *system's economy* by studying its parts alone in antimorphic foci. Not in the case of separate though exhaustive analytical levels stitched together in a frankenstein's monster multi-disciplinary approach, nor in the case of an interdisciplinary approach with a foci on the dialectical relations between these levels and their parts alone. The difficult task for economics lies in understanding and (re)structuring the system its economy in *both* its parts and relations *across* analytical levels. Here it needs to account for, principally and completely impractically; everything.

The first chapter in this thesis framed a meta-model of sustainability and equated economics as *certain means* towards *certain ends*; to move from the 'as-is' system state—if deemed unsustainable—towards the *certain* 'ought-to-be' system state. The second chapter in this thesis has discussed environmental problems in a system state being a logical result of economic theories and practices that consider the *human economy* as existing outside of their *constituting* environments—an integral part of neoclassical orthodox economics its cost-shifting practices (see Martínez-Alier 2012). Furthermore, in the second chapter the discussion has concluded that attempts to internalize the environment into orthodox economics appears doomed from the start, which this chapter has elaborated upon through critical examination of its foundational ontological presuppositions, epistemological claims, and methodological choices (see Spash 2012a).

Thus, starting more pragmatically than accounting for everything and *trying* to move beyond the gross impoverished reality of neoclassical orthodox economic, a start from an interdisciplinary philosophy of science has been proposed: To account for the elephant—the economy of the system—*without* dissecting it on the one hand, whilst on the other hand critically being aware and judging that the elephant is not a tree, a rope, a wall etc. Simply not constructing the elephant does not stop it from walking over us and trampling *us blind men and women all* in a fit of rage—in less poetic language referring to the disastrous consequences of continuing and ignoring environmental system relations degradation such as ecological relations and climatological relations. Anthropogenic influence on a system its parts and relations—leading to for instance, ecological 'destabilization' disadvantageous to human physiological needs, or 'overshoot' past ecological thresholds (see Meadows and Randers 2012)—do not necessitate our understanding and accounting for it to impact humans and our transformative ambitions of the *system's economy*. In other words, we ignore the elephant as a whole on the one hand, and its partialities on the other at our own peril—for the economy of system Earth, and valid subsystems delineations therein are insufficiently accounted for by either one alone.

Therefore, the next chapter will discuss a system theory approach to economy, starting from an environmental ecological focus (see Daly 1992b; 2015; Georgescu-Roegen 1971), to be expanded upon with i.a. a focus on moral economics (see Knox-Hayes 2015; Sayer 2015), with the aim to facilitate what this thesis will frame by the concept of *system* *economics*. The aim in proposing this *system economics* framework is to provide the start of a conceptual tool for use in resolving the contradictory sustainability operationalization and correct neoclassical orthodox economics its maladjusted costs and benefits articulations—which have not served to decrease environmental degradation and halt the socio-economic consequences thereof. In other words, the aim and intent is to contribute to moving economics towards its own purported goals; an 'optimal' allocation pattern, in line with the meta-framework proposed in chapter one—instead of the current results from its blind *cost-shuffling* and cost-increasing in a closed system; in other words the current dominant uneconomic economics.

Chapter 4 From Subsystem Economics Towards System Economics

If economics is theory and practice of anthropogenic (physical and social) activity in redistribution and transformation of the system's parts and relations, then a pertinent topic of discussion is; what is economics arguing to account for and trying to transform? The short answer is economy of course, however this is a deceivingly simple answer as the previous discussions on internalities and externalities of economy framings have illustrated. Economics as: "*A social science concerned chiefly with description and analysis of the production, distribution, and consumption of goods and services*" (Merriam-Webster 2018) is incomplete if its focus lies on a framing of economy as pertaining only to anthropogenic activity with clear inputs and outputs as pure externalities, and further delineated by socio-political boundaries.

Justified under judgemental rationality and structured critical pluralism (see chapter three) this framing of framing of the field of economy is thus rejected as pertaining to barely an open (sub)system of a larger closed or isolated system; the latter being where economy *should* be delineated at. The previously discussed social and environmental 'external' are thus more validly framed as *internal* to an economy system; requiring accounting for them in order to assess, and alter economy consistently and effectively, and to account for the costs and benefits of doing so validly. The environment is crucially a part or a subsystem, of the *system's economy* (see Kapp 1976) as discussed in chapter two. When the environment is framed as external this leads to obvious issues at certain thresholds in the empty-full world degree (see Daly 1992b; Daly 2015) for both stability of the current system state, and for transforming or developing the system state further towards desired 'ought-to-be' states. The start for delineating what economy is—and thus how to account for and alter it—has to start in a position markedly more holistically than the subsystem framing of economy that orthodox economics (too often implicitly) argues for.

This starting point then is framed here through a system theory approach under a working title of *System economics. System economics* for sustainability its initial point of departure is the embedded nature of the economic subsystem within its constituting social system. This embeddedness is justified by the social relations that are foundational for all human economic activity (see Rees 2015). The social system, in turn, is considered here to be a subsystem of its environment(s)—denoting whole of the system—in line with ecological economics (see Spash 2012a). Environment should thus not be considered as denoting 'nature' external to human, it should be understood here to denote a 'whole', of which the socio-economic is by definition a *partiality* within it.

Value pluralism is and emphasized in combination with a more relativist focus on utilitarianism involved in (e)valuations and value articulations. It is thus argued that economic should not aim to unify all (e)valuations nor force them into commensurate terms to each other entirely; for instance, ecological understanding, assessments, and projections should not be forced into the neoclassical discrete ‘exchange value’ articulations (see chapter two). Incommensurability of dialectical (e)valuations—emphasizing *relational* ‘properties’ in the system—with antimorphic (e)valuations in orthodox economics theory and practice is thus taken as cautioned. However, in line with structured and critical pluralism judgement *can* and *has* to be made for sake of ‘facts in values’ and the ‘values in facts’; thus commensurability has its place, but has to explicitly be justified beyond mere analytical convenience.

To elaborate: If the stability of a particular ecosystem within which an economic subsystem (within the social subsystem) exists does not articulate the stability of this ecosystem as valuable and thus economically desirable; i.e. its exploitation beyond *certain* thresholds and degradation are noted as more beneficial than its preservation and stability whilst the ‘services’, ‘goods’, ‘commodities’, that this ecosystem in its current state provides are valued, then the value of its stability—or the price of its degradation—is judged as undervalued. The economics built on such contradictory (e)valuations are self-degrading and *uneconomical* by any measure.

Another example for this point in the form of carbon sequestration by foliage: If such processes do not have a monetary value attached to it—or a form of evaluation that is commensurable in monetary terms—then in a market system damaging such a service is considered an externality when unpriced within orthodox economics. However, the consequences of such degradation of the ‘service’—i.e. decreased carbon sequestration—will affect the (eco)system within which the actors reside, regardless of pricing of such effects, or absence thereof. Such effects decreasing system stability will—depending on threshold and buffers of the system in relation to its stability—manifest into priced consequences as, regardless of whether the ‘service’ itself was measured, or articulated through monetization or not.

The gap in understanding of the *system’s economy* by a theory and practice of economics; its environmental blindness, or informational deficits (see chapter two) are thus inextricably coupled to its effectiveness, efficiency, or to use the more orthodox economic term; productivity can be judged. The criteria of the hierarchical or embedded nature of the subsystems—or dimensions—should thus allow for and facilitate this judgement, and to highlight the contradictory if not disastrous—i.e. uneconomical; unsustainable—results economic theories (already) have on restructuring of their system (see also MEA 2005). This approach furthermore should not necessitate explicit translation of dialectical concepts such as *certain* ecological stability into antimorphic concepts; the unfortunate turn the ecosystem services concept took once partially internalized by the orthodoxy of economy (see Gómez-Baggethun and Ruiz-Pérez 2011; Peterson 2010; Vatn and Bromley 1994).

System economics is then economics accounting for the *system's economy* that includes a-priori the environment, the social, and the economic in order to minimize the environmental and social blindness or informational deficits. The theories and practices of economics are—as previously discussed—*certain means* towards *certain ends*; where the means *cannot* contradict the ends (see chapter one). The ends of economics in their most abstract definitions are constructions of an 'ought-to-be' system state; equatable to the meta-framework of sustainability proposed in chapter one.

The *system's economy* in which humans operate contains by definition both anthropogenic and non-anthropogenic *parts* and *relations* constituting the *system's economy*. The *system's economy* is crucially a holistic concept referring to *all partials* and *relations* in the delineated system. That is not to say that all *partials* and *relations* have inherently equal a-priori relevance in any given context, however, the focus in accounting for the *system's economy* should explicitly be focussed on a holistic approach—as possible. Holism on analytical levels, and across analytical levels is impossible due to epistemological limitations (see chapter three). Thus social and environmental blindness or informational deficits are inherently impossible to eliminate entirely, though we should not fail to attempt to reduce them as much as we can in economics.

Another important point to *system economics* is that redistribution and transformation of the *system's economy* generally occurs through *both* anthropogenic activity, and non-anthropogenic activity. Inherent—'natural'—system stability should *not* be a point of departure a-priori. The *system's economy*—or environment—as a whole consists of biotic and abiotic parts and relations that 'work' on each other, 'work' in the system's economy in other words is not solely a term applied to anthropogenic activity. For instance, non-anthropogenic biological activity, ecological activity, climatological activity, geological activity, and astronomical activity shape the system; sometimes towards (certain) anthropocentric goals or desired 'stability', and sometimes against. For instance, the history of Earth, both in terms of life, and in terms of i.a. geology, is highly interrelated and marked by *change* as opposed to stability, change that is not always beneficial for anthropogenic goals, or even survival of the homo sapien species. The crucial point to take away from this departure point for *system economics* is that anthropogenic exosomatic 'work' is *not* inherently desirable—as orthodox economics approaches to economy seem to find very hard to appreciate.

All (re)distribution and transformation on different analytical levels and scales—macro, meso, micro—regardless of anthropogenic or other biological 'intent' in 'work' or abiotic activity, construct in their *total relations* the *system's economy* at a certain point in time, and projected over time through its changing system state. Only in accounting validly for the *system's economy* in a ever 'fuller' world (see Daly 1992b; Daly 2015; Rees 2015) exists increasing economic efficiency for moving towards desired normative criterion and possible scientific criterion *ought-to-be* system state(s). This system theory approach to economy and economics thus allows for inclusion of both 'human capital' and 'natural capital', as both being dialectical *parts* or *relations*, as opposed to parts of antimorphic-sovereign and independent dimensions or systems of their own accord as is the case within the orthodox economics framing.

Thus, (in)efficiency of (re)allocation of *purposeful* anthropogenic work in transforming the *system's economy*—i.e. the classical orthodox economics conception of itself and its field of subject—is dependent on what this author frames as three variables: Valid system delineation and categorization, degree of holism in accounting for the *system's economy* in its current state, and finally how well the anthropogenic actors understand and react to transformation of the *system's economy* resulting from 'work' and activity outside of their own (direct) influence—the latter including system relations such as of ecological nature, climatological, hydrological, and astronomical.

4.1 System delineations and thermodynamic considerations

An important dimension in accounting for a *system's economy* relates to its delineation—construction of (an) economy its boundaries. As indicated by the previous discussed in relation to externalities and internalities in chapter two, these delineations are crucial for validity and efficacy of economics. Irrespective of its specific construction—i.e. what is included *within* the system—all systems constructions can be categorized as either open, closed, or isolated. This framing, borrowed from thermodynamics (see Georgescu-Roegen 1971; Schrödinger 1945), allows for critical statements on the system framings of economy. In thermodynamics a system is either: Open, meaning heat and matter can move over the system boundary; closed, meaning matter cannot move across the system boundary—if heat can, it is an diathermic system and if heat cannot, it is an adiabatic system—or an isolated system, where neither heat nor matter can cross the system boundary.

If we can account for either an increase in matter-energy or a steady-state in matter-energy within a constructed economy system framing—i.e. what is considered an 'economy'—then the assertion can be made that it pertains to either an open or closed diathermic system as matter-energy crosses the supposed system boundary in some form or state. In the opposite case; where accounting for the *system's economy* shows a decrease in matter-energy totality within a delineated system, then it pertains to an closed adiabatic system. Thermodynamic system categorization is dependent on accounting of matter-energy in totality regardless of manifestation of matter-energy and its corresponding entropic state, and regardless of system scale—i.e. macro, meso, micro.

Earth as a system is generally considered a closed system, and the universe is generally considered as an isolated system (Glucina and Mayumi 2010). One of the foundational criticism of ecological economics is that the economy of orthodox economics is invalidly framed (implicitly) analogous to a thermodynamic closed, or even an isolated system. The previous discussion has however shown that *exosomatic* anthropogenic activity making up the orthodox framing of economy, in actually pertains to an open (sub)system within and thus a *partial* of the environment (see Adams 2014; Daly 1992a; Daly 2015; Georgescu-Roegen 1971; Glucina and Mayumi 2010; Lehtonen 2004; Spash 2012a). Thus reinforcing the need for economics to be based on a frame of multi-leveled ontological realism, critically structured and assessed through epistemological critical pluralism as proposed in the preceding chapters. The irreducibility of these levels to the physical means that the pertinent question is not one of *whether* thermodynamics applies to, or is relevant to economics; but rather *how* it relates as to economics.

4.1.1 From perpetual motion machines towards diminishing returns understanding

To take a step back let's briefly discuss what thermodynamics is to highlight *why* it is so crucial for *system economics* and sustainability. Thermodynamics is study of energy within a system, relating to its distribution at any given time, and its transformation over time. Originating from the study of steam engine efficiency in the 19th century, Georgescu-Roegen (1971) and Boulding (1966) both argued for the theoretical validity and practical necessity of considering the thermodynamic laws their application to the field and disciplines of economics. Together with an emphasis on re-embedding economics as a subsystem of ecology relations of the environment the argued for application of thermodynamics signaled an formal criticism and a call for re-embedding economics back into its physical reality. These criticisms together became two foundational aspect of the—then newly emerging—heterodox discipline of ecological economics (Glucina and Mayumi 2010).

Over forty-five years onwards, the fact that ecological economics is still firmly in the heterodoxy—with thus arguably little interest in dominant sustainability and economics debates to its critical 'voice'—signals the continuing importance of emphasizing these two foundational principles towards economics. Environmental degradation has continued and increased, in combination with increasing anthropogenic climate change. The response from orthodox economics has been the taken for granted panacea of economic growth and ever further expansion of the commodity frontier to apply the same orthodox economic logic of an external environment (see chapter two) that has led to the problems it is envisioned to alleviate. Likewise the criticism of orthodox economics' economy being framed outside of physical reality and our thermodynamics understanding of it still being an ongoing debate (cf. Fisk 2011; Kovalev 2016).

The first law of thermodynamics of a system states that no energy is created or destroyed in an isolated system. As Georgescu-Roegen (1971) noted, the first law of thermodynamics does not imply direct contradiction with an newtonian economic understanding of a system and scarcity within. The first law of thermodynamics frames the 'workings'—i.e. 'heat' or 'work' within the system—of the universe as a matter of energy transformations of finite matter-energy (Glucina and Mayumi 2010):

> *Thermodynamics essentially describes transformations of energy from one form to another, and the modes of these transformations are called 'heat' and 'work.' [..] Energy is an abstraction from more "real" quantities, such as height, temperature, pressure, velocity, mass, etc. These are real quantities in that they can be measured directly. Consequently, there are many types of energy: gravitational-potential, kinetic, thermal, elastic-potential, electrical, chemical-potential, radiant, and nuclear. With this in mind, a rough definition for energy may be 'the capacity of a system to do work.'* (Glucina and Mayumi 2010: 12).

Also referred to as the 'law of conservation of matter-energy', the first law of thermodynamics frames the existence of finite limits and thresholds of a system—closed or isolated system. Any system, open, closed, or isolated, pertains to finite matter-energy, either within it, or in the case of an open system relating to 'internal' matter-energy plus inputs and minus outputs. A hard implication of the first law is a restriction to efficiency, all processes are recast on the micro analytical level of the *system's economy* as constant transformation and redistribution of finite matter-energy in *certain* combinations; 'efficiency' is by definition impossible beyond a ratio of 1:1, as no matter or energy is created or destroyed but only redistributed and transformed.

The law of conservation of matter-energy informs thus the notion of efficiency and productivity as framed by orthodox economics as very much constituted by subjectivity. To explain briefly this crucial point: The transformed 'output' matter-energy is more desirable (higher valued by *certain* social actors) in its 'outcome' 'produced' transformed and redistributed state, as compared to the 'input' distribution and complexity state of the matter-energy before transformation. However, framing an isolated *system economy* only by the first law thus presents the system as a thermodynamic equilibrium of matter-energy, where the dynamism in the system, and of the system, are the result of complexity by combination; of merely shuffling and combining the same pieces around perpetually and forming new complexities by combination that are 'costlessly' reversible (see Georgescu-Roegen 1971; Rees 2015).

The criticism against orthodox economics' logic and framing of the *system's economy* in relation to thermodynamics, can be emphasized by briefly discussing what Georgescu-Roegen (1971) considered orthodox economics' newtonian understanding of physical reality, and the perpetual motion machine that is implied by it. Starting from the previously discussed and proposed framework for *system economics* a newtonian understanding of a *system's economy* would allow framing of an economy as a matter of constant (re)distribution and transformation through combination of its finite energy and matter. It would allow for a circular notion of economy, wherein there are no irreversible flows, and outputs of processes of the—open subsystem—anthropogenic economy to be used as inputs once again at no added-costs (Georgescu-Roegen 1971; Glucina and Mayumi 2010; Rees 2015; Victor 2010; Zencey 2013). We know however from the study of thermodynamics, and by placing it in the multileveled ontology for *system economics*, that this newtonian understanding of economy as a representation of physical reality is an impoverished one. In analogy to Scott's (1998) usage of the term impoverished reality in reference to the fiscal tree. A perpetual motion machine framing of a *system's economy*, as orthodox economics considers its economy—leaving the invalid system delineations aside for a moment—is contradictory to our physical understanding of reality in general, and of the *system's economy* of system Earth in particular (Glucina and Mayumi 2010; Rees 2015). This is where the second law of thermodynamics thoroughly throws a further wrench into this perpetual motion machine understanding of the *system's economy* in orthodox economics.

The second law of thermodynamics states that the system's finite matter-energy becomes irreversibly, and unidirectionally more evenly distributed—at an indeterminate rate. This dissipation of matter-energy within a system—on the micro level of analysis—is denoted by the system's entropy. A designation of 'low entropy' is a system state with more unevenly distributed energy, and a 'higher entropy' designation refers to a system state with more evenly distributed energy (Georgescu-Roegen 1971; Glucina and Mayumi 2010). Stating a system's state of entropy as high(er) or low(er) is relative to a timescale or in comparison to another system; thus comparative and relative by definition.

For instance, looking back into time towards the rapid expansion of the universe; the 'big bang' or 'big inflation' roughly 13.8 billion years ago is a system state of the universe where matter-energy was in a lower entropy state then in the present. Likewise, projected into the future the 'heat-death' of the universe is the theorized state of the universe system where the entropic state of the universe system will reach such a degree of even distribution of matter-energy that no further 'work' will be possible between the matter-energy anymore. Heat being the result of 'work' between matter-energy interacting is theorized to become impossible once a thermodynamic equilibrium is reached—if such theories prove to be correct.

To return from these truly distant timescales to a more human scale; orthodox economics' understanding of the *system's economy*, irrespective of (sub)system delineations, conflicts crucially with the laws of thermodynamics as these pertain to the state and redistribution of matter-energy within it over time. The *system's economy* and the anthropogenic economy subsystem within it are not reducible in all its analytical levels to our understanding of physical reality; however the *system's economy* is crucially embedded and thus bound by the micro level of analysis, and our thermodynamic understanding of it. Let any economist who disagrees provide argument what physical matter-energy—in any form—even the most metaphysical thought of a human being, that is physically constituted and thus not bound by our physical understanding—and thus our understanding of thermodynamics.

In the preceding chapters the discussion has argued on the environment—i.a. dialectical ecological relations of the *system's economy*—and economics that the latter its embeddedness *within* the former makes it invalid and uneconomical (i.e. inefficient, ineffective, unsustainable) to frame economy as an isolated and independent system. Likewise economics cannot be allowed to be a trade of illusionists claiming validity, or metaphysical miracles through their illusions—such as the perpetual motion machine economy (see Georgescu-Roegen 1971; Rees 2015), perfect substitutability (see Daly

1992b). These illusionist tricks simply do not reverse or nullify our thermodynamic understanding of the physical reality that economy is embedded *within*.

4.1.2 Entropic decay and system economics

Through considering the concept of entropy and entropic decay we can highlight further how thermodynamics informs our understanding of limitations to transforming the *system's economy* of system Earth. When applied to economics the concept of entropy or energy distribution has generally been referred to as the amount of 'free energy' and 'bound energy' in the system state at a given time. Free energy referring to low entropy form—relatively unevenly distributed—allowing for more 'work' to be done within the system by virtue of the unidirectional flow of entropy. As all energy in an isolated system dissipates into a more evenly distribution, 'acting upon' low entropy energy 'frees' energy. For instance, burning a log of wood or a lump of coal—i.e. a form of 'acting upon' or 'work'—distributes the energy more evenly in the system;increasing the entropic state, though crucially this redistribution is from which humans gain benefits such as heat (Georgescu-Roegen 1971).

Here the first law is important to reiterate; no energy or matter is created or destroyed. Rather, the combination of energy or matter identified in its specific distribution —its state of entropy—is 'destroyed'. The relations forming a part as identified on a higher analytical level—in this case a log of wood—is 'destroyed' through the increasing dissipation of energy in the system. The concept of novelty by combination (see Georgescu-Roegen 1971) frames what occurs in this situation; for instance, in the case of the elephant in Saxe's (2017 [1872]) parable joining together with other elephants they together—as partials—form a 'new' novelty through their combinations: a herd of elephants. The herd itself is in certain situations and from the point of view of certain analytical levels considered a part in its own right—of, for instance, ecological relationship. In similar fashion a *certain* group of humans delineated by, for instance, a spatial proximity, socio-political drawn boundaries, or socio-cultural identifiers are identified as an sociological entity, a country, an ethnicity etc. Likewise a *certain* group of humans are considered to make up through their constructed institutions, their activity of redistribution, transformation, and exchange of materials what is classically referred to as an 'economy' of a country or region. In other words parts of a particular analytical level form relations that are consequently identified on a 'higher' different analytical level and reified as parts.

An elephant is made up out of i.a. specific biophysical body parts, organs, and microbial colonies; in turn these are made up of i.a. combinations biological cells and organelles; these in turn by i.a. combinations of molecules; atoms; down to the smallest ‘elemental’ particles we can theorize or ‘observe’. One could determine the amount of cells that an average healthy adult elephant is made up of, however simply that amount of cells does not ‘make’ what is, or is not the animal that we call an elephant—leaving aside the problem of ‘making’ the ‘average elephant’ due to differences in species, and variations within these. Crucially, it is the *certain combinations* of particles that form cells, *certain combinations* of cells that form organs and biophysical body parts, and *certain combinations* of these to form ‘an’ elephant.

This ‘*novelty by complexity*’ (Georgescu-Roegen 1971) or novelty through combination cannot be freely (physically) reconstructed once the matter-energy—i.e. parts—that constituted the relation as a part on higher analytical level is dissipated; for instance, once the log of wood is burned, or once the majority of the elephants in the herd die. That is to say that the social construction is not inherently impossible—we can freely (re)construct our *constructions* of what we consider ‘a log wood’ to be, or how many elephants make up a ‘herd’ of elephants. However, the physicality and the ‘work’ that was possible with this *physicality* of ‘the log of wood’ is not possible anymore, and the same applies to the ecological relations as physicality that ‘herds of elephants’ at least partially constitute. Granted, the example of the elephant is a tenuous one—application of entropic decay to ‘higher’ levels of analysis is questionable as will be discussed further on in the discussion—however it does serve to illustrate novelty by complexity, to which the discussion will return to later in the text.

Returning to the unidirectional flow of entropy; the second law of thermodynamics shows us that the same energy cannot be used twice—change; (re)distribution; transformations; system degradations have an irreversible cost in an isolated system. As Glucina and Mayumi (ibid.: 15) state: “[..] *nature demands a ‘tax’ whenever heat is converted to work. We can never achieve 100% efficiency, no matter how good our technology is.*” The implications is that due to the entropic cost of all ‘work’ outputs of the anthropogenic economy cannot be used as inputs again without ‘cost’; in other words the efficiency of ‘work’—considered in the correct framing of the *system’s economy*—is by definition less than a 1:1 ratio; any ‘work’ within the system is by nature of the thermodynamics of the system *degrading* to its distribution of matter-energy (Glucina and Mayumi 2010). Stability in a system and a notion of ‘growth’ as increased ‘work’—anthropogenic and non-anthropogenic—in the system comes at cost to the system its entropic state. The term transformation then becomes synonymous with redistribution; as all transformations or ‘work’ in the system pertains to redistribution of matter-energy through entropic processes. Furthermore, in light of the first and second laws of thermodynamics; the terms transformation and redistribution are more apt to describe the *physicality* of what occurs through the processes framed by classical framings of 'production' and 'consumption'—that is not to deny the methodological uses these framings offer for understanding and assessing *constructions* around these physicalities (see chapter three for the irreducibility, though embeddedness of constructions within a physical reality on the one hand, and the constructed and fallible nature of *all* epistemology on the other).

Through the 'work' in the system the matter-energy now being more evenly distributed it cannot be reversed to lower entropic form distribution without 'cost'. Reversing the state of distribution in the subsystem of the matter-energy to its former state 'costs' the system 'proper' (closed or isolated) increased entropic decay. The reversal of matter-energy is thus not impossible purely in consideration of thermodynamics; but it is not possible freely without cost reflected in relatively higher state of entropy state of the closed or isolated system. Thus this re-affirms the crucial importance of delineating the 'proper' system for economics, as accounting for any open subsystem does not give much insight into *real* thresholds and limits. In an open system, such as the orthodox economic framing of the anthropogenic economy entropy can be seen as unimportant or even reversible. Any open subsystem can appear to 'cheat' entropic decay at 'external' cost of its surroundings if its surroundings are not accounted for; an effect that might provide some explanatory power to Daly's (1992b) observation of the empty world economic logic continued hegemony through orthodox economics, and thus the nascent acceptance of a 'new' full world economics revolution that ecological economists have argued for.

4.2 System Earth, dynamism, and complexity

Accounting for the *system's economy* of system Earth as a relatively closed system can be stated as—for analytical sake simplified here—pertaining to two sources of matter-energy in relatively low entropy state of relevance for human beings and life in general on Earth. Firstly; system Earth's 'internal' biochemical and geological resources parts in totality and systemic relations—i.a. geological minerals, the biosphere, ecology, climate, and atmospheric contents. Secondly; system Earth's its external source of limited flow of solar radiation from Sol (Daly 1992a; Georgescu-Roegen 1971). With sol itself and its flow of solar radiation being subject to entropic decay as well; as the solar radiation that reaches Earth is set to diminish over the next approximately five billions years through the hydrogen depletion within Sol's core—as its hydrogen is 'used up' it is theorized to transform into a red giant with disastrous consequences for life on system Earth if it is still around at that point. However, for the timescale implicit in anthropocentric economics—generally not concerning billion year scales—this diminishing rate of solar radiation reaching system Earth is perhaps of minimal importance to the discussion at hand here. However, it is mentioned to illustrate that even the seemingly infinite source of low entropy that is Sol; is principally not that—infinite—but rather subject to thermodynamic workings as well.

System Earth thus functions as an relatively diathermic closed system; very little to no energy crosses its outer atmospheric boundary as matter—relative to system Earth's internal matter-energy—though, matter-energy does cross its boundary in two significant ways as energy; in the form of heat dissipating outwards from system Earth—output to its 'surroundings' or solar system environment—and solar radiation from Sol inwards into system Earth as an input (Glucina and Mayumi 2010). In other words, the matter-energy in system Earth, minus its output of heat dissipation, and plus its input of solar radiation frame together a *finite scarcity of matter-energy*—and thus 'work' and *physical* transformations possible—in the system at any given time, and over time.

The two factors, solar radiation and Earth's 'internal stocks' of low entropy, combine to form in a given—temporally isolated—analytical framing system Earth's 'stocks' to use an classical economic term. This finite 'stock' has a *certain* distribution; with *certain* combinations of this finite matter-energy existing at this point in time—relating to possible combinations as framed by our thermodynamic understanding. The system's finite matter-energy in a this *certain* distribution and *certain* combinations is across identified across various levels of analysis as different parts and relations; providing a barrier for commensurability and singular expression of matter-energy of the system—though crucially, this epistemological limitation to our ability to account for the complexity by combination of matter-energy.

Sol's radiation that is considered here as an input into system Earth constitutes a larger source of low entropy energy by orders of magnitude than the Earth's 'own internal' resources: "*[..] the highest estimate of terrestrial energy resources does not exceed the amount of free energy received from the sun during four days*" (Georgescu-Roegen 1971). As crucial as this sunlight is as an input into processes at various levels of analysis to system Earth—for instance, climatological, ecological, biological—the low entropy energy itself is of little use for direct *endosomatic* use for human beings; other than for e.g. staying warm—an obvious caricature for illustrative purposes. For the oxygen required to breathe we rely on the sunlight to be converted by other biological and abiotic parts and relations in the system—for instance, ecological relations, climatological relations, and geological processes. For the nutrition humans depend on photosynthesis by plants, algae, and phytoplankton—in varying degrees directly or indirectly ultimately down the food chain—before Sol's 'plentiful' low entropy becomes relatively *endosomatically* useable to satisfy i.a. the nutritional need of human beings—surely one of the main and most basic provisioning aims of economics.

Thus, as ecologists and ecological economists have pointed out (see Adams 2010; Daly 1992a, 1992b, 2015; Lehtonen 2004; Spash 2008, 2012a, 2012b), humans and our subsystem of the anthropogenic economy depend on our environment and *certain* i.a. ecological relations within it, regardless of how much plentiful low entropy from Sol reaches Earth's surface and atmosphere. Solar radiation from Sol is itself not—directly—the source of low entropy *alone* that informs scarcity in relation to human survival; thus solar radiation influx is not *directly* a valid nullifier of scarcity for satisfying human biophysical needs. Rather the 'internal' finite matter-energy of system Earth itself—for instance, in its geological, biochemical, bio-ecological, climatological, *and* anthropogenic manifestations—and how these 'work' on the low entropy input from Sol and in relation to each other that constitute relevant scarcity in anthropocentric and biocentric economics of system Earth. These manifestations of matter-energy, in the e.g. geological, biochemical, bio-ecological, climatological, *and* anthropogenic parts and relations are what is crucial for consideration of limitations to anthropogenic redistribution—i.e. economics. Re-affirming the proposed embeddedness of the anthropogenic economy within the environment, and the physical.

4.2.1 The low value of low entropy

System Earth, not being an isolated system or closed-adiabatic system, but rather a closed-diathermic system with significant input of low entropy energy from Sol, the possibility of relative equilibrium of matter-energy in the system is not excluded—dependent on the level of heat dissipation as output. On the face of these characteristics of system Earth and considering only matter-energy on a micro level of analysis, one could make the mistake to conclude that the second law of thermodynamics is not of significant concern to economics—if the low entropy input from Sol is higher than the heat dissipation output from system Earth. However, for anthropocentric purposes in relation to the survival of individuals and of the species—relating to our biophysically dictated needs—*certain* combinations of matter-energy, relating to *certain* entropy states are desired and needed for human survival.

As Georgescu-Roegen (1971:17) states: *"Man, we should not forget, struggles for entropy but not for just any form of it. No man can use the low entropy of poisonous mushrooms and not all men struggle for that contained in seaweed or beetles.*" What is 'valued' by humans—both in terms of biological needs and orthodox economic concepts of exchange value—is then rarely the entropic state of a system itself. Though, as previously stated it *is* crucially related to the matter-energy distribution state because of the amount of 'work' that is possible within it, and thus the combinations of matter-energy that are possible within it. For instance, the entropic state of a system with an atmospheric oxygen level that is breathable and 'healthy' for current human physiology is poorly expressed solely by a measure of high or low entropy. However, the finiteness of energy-matter, its distribution and thermodynamic workings of the diathermic closed system Earth does provide understanding for the very real limitations and thresholds to what state(s) of entropy are required to allow combinations of matter-energy—on a relatively micro level of analysis—such as molecular oxygen to exist, and for instance, the atmospheric regulating relations on macro level of analysis allowing for Earth's atmospheric composition and structure.

For another example: It is not the entropic state of matter-energy that informs us the importance of fresh water required for human consumption. Rather it is the combination of matter-energy in *particular* complexity relations, at various analytical levels of analysis—e.g. of particles; of atoms—to form water molecules. The same applies to the combination of water molecules on a relatively more meso level of analysis; as the molecules of hydrogen-dioxide combine with other molecules to form a *certain* 'purity' of water, constituting a range of potable water that is drinkable for us humans—not pure hydrogen-dioxide, but not too impure water either. Thus returning to the notion of irreducibility *and* embeddedness. As potable water is not *merely* a matter of a social construction; matter-energy has a range or point(s) of distribution—entropy—where it can exist in form of water; a *certain* low(er) level of entropy (distribution of matter-energy) is required. Thermodynamic understanding of physical reality, chemistry, and hydrological understanding of 'water' inform us—directly and indirectly and relating to each other—that at *certain* high(er) levels of entropy of system Earth what we identify as potable water cannot physically exist. On the one hand the matter-energy in its combination of e.g. potable water being epistemologically irreducible to its entropic distribution is of crucial importance, but on the other hand though, the finite amount of matter-energy in the system and the system's state of (dis)equilibrium, and the distribution (entropy) state of the matter-energy frame limitations and constraints to the combinations possible within the system at a given time, and over projected future time.

Thus it not the primary matter of low entropy input from Sol, in relation to the output of heat dissipation that frames the *system's economy* of system Earth that frames or nullifies scarcity for anthropocentric *system economics*. The relative plentiful low entropy input from Sol is input of low entropy matter-energy in *certain* combination at a *certain* state of distribution. In other words, *exosomatic means* are required (see Georgescu-Roegen

1971)—returning to Daly's (1992b) telling conundrum that if this 'natural capital' such as solar radiation would be sufficient then no transformation or redistribution—i.e. active anthropogenic 'work' in the system—would be necessary. Whether this concerns anthropogenic *exosomatic* activity (i.e. 'work') on other parts of the system is required to make the input of solar radiation *directly* 'useful' for humans and anthropocentric economics—for instance, constructions of shelters, transforming minerals into photovoltaic cells, agriculture of photosynthesising plants to 'harvest' indirectly solar radiation in a food-chain leading to combinations of matter-energy that is nutritional to humans. The notion solar radiation constituting relatively 'free' energy for anthropogenic economies is thus rejected, and an emphasis of embeddedness of anthropogenic economics into both a physical reality, and a bioecological reality reiterated, with an added emphasis on the 'cost' of all 'work' in a *system's economy* of a relatively 'full world' context (see Daly 1992b; 2015).

Simply the input of matter-energy into system Earth thus does not nullify notions of scarcity; humans desire and need *certain* combinations of matter-energy at *various* states of entropy, within certain thresholds. It is rather pointless, if not downright sadistic to suggest that starving, dehydrated, or shelterless human being would merely need to soak up the plentiful solar radiation to solve their need for lower entropic matter-energy to keep alive.

4.2.2 The biosphere and the indeterminacy rate of entropic decay

In relation to thermodynamics of a system, the organisms of the biosphere within it were conceptualized by Schrödinger (1945) as open systems—metabolizing low entropy from their surrounding environment(s) to maintain themselves in a relative steady-state; a state of life. Here the emphasis lies on metabolising, as organisms are not exempt from the thermodynamics of their (closed or isolated constituent) system; system Earth.

Two principles are then of crucial concern relating to the biosphere of a system and thermodynamics. Firstly, the aforementioned inescapable fact that organisms are open (sub)systems. Life, due to its inherent 'quasi-steady state' of 'not being dead', does not counteract or reverse thermodynamics of a system—life does not create or destroy matter-energy, nor does it counteract or reverse entropic decay of its constituent 'proper' *system's economy*. Accepting this first premise allows for confident statement that the only way organisms in a closed system can maintain their quasi-steady state of staying 'alive' is through accelerating the entropic decay of their constituent system through 'working' on the low entropy of their environment—metabolising *certain* matter-energy in low entropy state from their environment into higher state entropy (see Daly 1992a; Georgescu-Roegen 1971; Schrödinger 1945). Life of the biosphere is in this sense in a constant struggle against entropy decay; where the end of the quasi-steady state of organisms means the death of the open (sub)system in question; end of the life of the organism. Thus Georgescu-Roegen (1971: 11) argues: "[..] *from all we can tell now, the presence of life causes the entropy of a system to increase faster than it otherwise would*."

However, this is an obvious theoretical hypothetical statement, as the absence of life in the system would not mean a system inherently closer to a thermodynamic equilibrium. In other words, an a-priori statement on that a system would have a lower entropic decay rate should be made cautiously keeping in mind that it is difficult to state what the matter-energy now constituting organisms would have taken shape of otherwise—and crucially what kind of 'workings' this matter-energy would have otherwise have had in the system. The crucial message that is pertinent here to the constituent interactions of the biosphere with thermodynamics of the system is its implications for the '(in)stability' of the *system's economy*; the implications for sustainability.

The second principle concerns the *indeterminacy rate of entropic decay* and its relation to life and its constituent system. The *direction* of entropy is fixed to the flow of time. Matter-energy of an isolated system becomes irreversibly more evenly distributed allowing for less 'work' to be done with it—relating to the construction that this more even distribution allows for less complexities through combinations (see Georgescu-Roegen 1971). However, the *rate* of this entropic decay is not fixed. As Glucina and Mayumi (2010) state on the second law of thermodynamics; the unidirectional and irreversible flow of more even distribution of matter-energy in an isolated system does not inherently imply or dictate a timescale in itself but depends on the amount of 'work' done in the system. Crucially, the rate of entropic decay is not prescribed by the first or second laws of thermodynamics. Thermodynamics understanding of a system frames only the amount of 'work' or transformations possible—i.e. the 'work' that the finite matter-energy of a system is capable of between its 'current' entropy state and its high(er) entropy system state where no further 'work' is possible.

Thus; although the presence of life in a system seems to inevitably increase the rate of entropy of the system through its 'workings', the rate of increase in entropic decay is not given by our thermodynamic understanding. Rather, the *indeterminacy rate of entropic decay* in relation to the bio-ecosphere allows for a dynamism of more macro-level structure and distributions in the system. Matter-energy in *certain* combinations relate to different rates of increase to the entropic decay of the system. The *indeterminacy rate of entropic decay* thus informs us that although physical stability of the system as thermodynamic equilibrium is impossible (conservatism of matter-energy in a *certain* non-degrading distribution pattern), a *certain* long(er)-term macro stability is plausible through *certain* combinations of matter-energy.

4.2.3 The green economy

The bio-physiologically dictated human needs of i.a. nutrition, hydration, and breathable atmosphere have to be considered as having undeniable biological security thresholds to survival of individuals, as well as to the whole species of human beings. Beyond thresholds of a ‘full world’ (see Daly 1992b; Daly 2015) these require maintaining an ‘artificial’ utilitarian stability of the system’s environment. In order to sustain the non-anthropogenic parts and relations of the system—for instance, the climatological and bioecological parts and relations—such stability can allow for relatively more *endosomatic* fulfillment of the i.a. nutrition, hydration, and breathable atmosphere security thresholds. Attempts at substituting these by more *exosomatic means* in a ‘full world’—i.e. extensive and costly substitution—needs to be measured not just in their initial cost, but also against the effect this shift and the accompanied increase in anthropogenic work required for them has on the desired stability of the system (Rees 2015).

In the absence of anthropogenic acting—i.e. ‘work’—upon the system’s matter-energy it is important to note that other biological entities and system relations including those of abiotic nature—e.g. climatological, geological, astronomical—also accelerate entropic decay through their ‘work’ on matter-energy. As Georgescu-Roegen (1971: 281) states; ‘*the whole physical process of the material environment is entropic too*’. There is not an external ‘balance’ or system state of ‘order’—a notion of intrinsic stability of the *system’s economy* of system Earth in line with anthropocentric needs is misplaced wishful thinking. The question on system stability is rather about the *possible* entropic decay acceleration of anthropogenic—conscious—redistributing and transforming the system, juxtaposed to a system state where anthropogenic activity is oriented at relative conservatism of entropic decay for ‘internal’ anthropocentric utilitarian purposes.

Irrespective of what ‘ought-to-be’ system state(s) are constructed and what normative criterion guides guide these; a certain ‘stability’ of system Earth’s environment(s) is by definition *needed* for humans; as holds true for any and all organisms their continued existence as individuals and as species. Stability or instability, alike order and disorder of a system, are thus inseparable from a *certain* notion of ‘economical’ or utilitarian purpose(s). A *particular* ecology and ecological stability is desired; stability of the environment of a system *for* anthropogenic goals—not as separate or paradoxically oppositional to it, where orthodox economic theory and practice is judged as the latter.

With this in mind we have to explore and acknowledge the possibility that the bio-ecosphere could be more ‘efficient’ vis-a-vis the *indeterminacy rate of entropic decay* in converting solar radiation, compared to *certain* ‘internal’ to system Earth resource-heavy *exosomatic means* of ‘working’ on the low entropy of Sol’s radiation. The *real* green economy of system Earth would then turn out to be a lot more literal green than the current application and projection of the term as to double-down on the orthodox economics of business-as-usual with a hint of greenwashing (see Constanza 2012). To reiterate such a ‘green economy’ would not inherently mean *less* anthropogenic work and influence on the *system’s economy*; simply different ‘work’ that means less destabilization of system Earth’s *system’s economy.* To truly do justice to this topic of the biosphere thermodynamic efficiency versus past anthropogenic transformation of the *system’s economy* of system Earth is however beyond the scope of this thesis, and is thus proposed for further research in the framing of the proposed meta-frameworks for sustainability and *system economics*.

Chapter 5 Discussions

From the preceding discussions it should be clear that for *system economics* the *oikos* of relevance is proposed by this author to be system Earth—as a closed diathermic system—in line with i.a. Boulding (1966). System Earth its boundaries are pragmatically more separable from an external environment, as a diathermic system with relatively limited inputs and outputs, as compared to orthodox economics' supposed 'pragmatism' in framing socio-political or 'market' economies. Orthodox economics' supposed 'pragmatism' cutting off ecological and social relations across its supposed systems boundaries are rejected, and as discussed prior; significantly risking, enabling, justifying, and reifying *uneconomical*—i.e. unsustainable—'economic' structures and institutions within system Earth.

Through 'globalization' of socio-economic relations—such as 'trade', environmental and social exploitation, externalization of manufacturing, increasing complexity and intensity of product, waste, consumption chains—the implicit and taken for granted notion of accounting for economy within these socio-political boundaries has increasingly become more invalid in this author's informed opinion; as discussed in relation to social relations constituting anthropogenic economics and their environmental transformative impacts crossing increasingly the supposed economy delineations without being validly accounted for—regardless of being the result of absence of knowledge of these; i.e. epistemological blindness to these relations on the one hand, and atheist or agnostic attitude towards these relations for competitive advantages and intentional socio-environmental 'externalization' of costs.

System Earth is not unified under one governmental or coherent governance body; what is considered an economy in correspondence with *certain* envisioned 'ends' towards which this economy is envisioned to develop towards are quite clearly related to socio-political divisions—constructions such geo-political regions in the form of countries; socio-cultural divisions such ethnicities, and further socio-economic power divergences within these divisions; merely for analytical convenience here grouped together under the umbrella term of socio-political divisions. The orthodox economic delineations of economies are thus based and justified on, and the result of socio-political notions of sovereignty—of, for instance, a groups or a spatial locale. This framing of economy that orthodox economic theories, practices, and institutions are both built upon and reify, are not valid closed system delineations of a *system's economy*. As discussed in the preceding chapter these are open (sub)system delineations of economy by their nature; neither validly framing an environmental nor a socially closed system—in addition to not accounting exhaustively for what is supposed to be 'internal' to their own delineations (see chapter two).

Thus these classical orthodox economic framings of economy, though *possibly* reflecting socio-political boundaries adequately, are nonetheless poor delineations for a *system's economy*—an obvious point that nevertheless serves to be reiterated; (system) economics is not just about constructions such as socio-political boundaries and normative criterion, but also about a physical environment and reality, one that cannot 'freely' be reconstructed and has to be accounted for validly for effective restructuring of it. Institutions, theories and practices built upon this understanding of economy, are highly likely to result in inefficient restructuring—once full world thresholds in system Earth are crossed—causing destabilization of desired and needed system relations; in other words unsustainable and uneconomical practices.

The proposed frameworks for sustainability as ends, and *system economics* as means are meta-frameworks for system Earth. In the absence of true international formal economic governance the application of these meta-frameworks need more specification, and pragmatic adaptations for more micro and meso scales such as national, regional, local context delineations and focusses. However, the meta-framework has strongly asserted *certain* limitations and dependencies. The meta-framework does not dictate hard limits to what *specific system economy* of system Earth is required for anthropocentric ends, merely that *certain* normative criterion such as a world population of seven billion, combined with a *certain* 'consumption' pattern relates to *certain* immovable limits and thresholds to the *system's economy*—there are simply no 'triple win' scenarios that are feasible.

5.1 System economics, 'growth', and 'technology'

Understanding and acknowledging the thermodynamics of a *system's economy* on a micro level of analysis allows for firm statements on notion of efficiency relating to *exosomatic* material 'technology' being bound to lower than 1:1 input to output metabolic ratios. The importance of accepting this notion towards growth cannot be overstated; decoupling in terms of 'technological progress' can simply not be valid in terms of material resources—matter-energy—ratio, lest the first law of thermodynamics or the physical embeddedness of the socio-environment would be challenged. Thus meaning orthodox 'economic growth' as relating to matter-energy has very real boundaries in terms of micro level of analysis that is a constitutional level of analysis for the socio-environment—adding to the limitations to 'economic growth' from the i.a. discussed ecological thresholds of the environment *within* system Earth.

To briefly reiterate the discussions of the preceding chapters for clarification of this point: All anthropogenic constructions and actions denoted by orthodox economics as production, provisioning and exchange, and consumption, are by definition that; anthropogenic, pertaining to social relations of *biological* human actors. Meaning that, social relations are irrefutably the foundation of these 'economic' constructions and actions in every case where this pertains to a system wherein more than one human being operates. A system approach informs the importance of considering indirect and unaccounted for social relations. An example of this is the need for inclusion of for instance, 'appropriation' of—completely unappropriated by humans—natural resources in how these and the transformative actions upon them indirectly relate to the other human beings in the system These influences can for instance, be ecological, hydrological, or climatological changes to a micro (e.g. regional, national) a or macro scale (i.e. system Earth) relatively open or closed system.

Thus, even in 'complete' absence of *direct* social relations—for instance, in a case of cutting a forest down in a remote part of the world—the *indirect* consequences of transforming and affecting the distribution of e.g. matter-energy such as in analytical levels of biology, ecology, of climatology; affects the system and with that other human beings within it to varying degrees, and with varying and often diverging (short-term) desirability of such transformative 'workings' on the *system's economy*.

Thus, the preceding discussion of thermodynamics and relating to the *system's economy* of system Earth allows for reiterating that 'economics' by definition is embedded within 'the social'—as any 'workings' upon a system's *partials* often means changes to larger relations and thus of the *whole system's economy state*—and the social within 'the environment' of a validly delineated closed or isolated system; the oikos proper for *system economics*.

Development goals can be reached through offsetting direct accounted for socio-economic costs through methods such as spatial distancing, and segmenting or complicating product chains—thus hiding the socio-economic costs and moral relations behind such offsets. Hidden, but not actually decoupled from these costs. In other words, these are cost-shifting practices (Martínez-Alier 2012) between actors, not actual cost-reductions or benefit increases of the *system's economy* as a whole. Likewise reaching development goals can be offset against environmental costs whilst not *inherently* cause socio-economic costs until certain thresholds of a micro, meso, or macro system are reached—indicated for instance, by; a full(er)-world context (Daly 2015), overshoot (Meadows and Randers 2012), or footprint metrics (Wackernagel and Rees 2015). Beyond such i.a. ecological, climatological, hydrological thresholds cost-shifting *does mean inherent* though possibly hidden or unaccounted for *indirect* socio-economic costs—likewise possibly offset spatially or temporally. Hidden or unaccounted for costs—but costs nonetheless.

Cost-shifting in a closed system 'full' context scarcity alteration is thus is directly fed back into it, though too often unaccounted for—in combination with increasing our footprint and dependencies on this system its stability through 'growth' as throughput increase is thus a very short-sighted policy-frame. The logical result of such 'growth' or transformation of the *system's economy* cause exponential degradation of the system. Degradation that is beyond a full-world context (Daly 2015); overshoot (Meadows and Randers 2012); or too large of a footprint (Wackernagel and Rees 1998; Wiedmann et al. 2015) inherently impossible to sustain, even for the term of several human lifespans.

As controversial as such a statement would be to many if not most relativist epistemological dogma's; even the field of human culture and the diffuse subject of thoughts and social constructs are undeniably physically constituted by matter-energy—though their complexity irreducible to this matter-energy (see chapter three). The latter being a matter of controversy in turn with many if not most positivist epistemological dogma's. As chapter three has discussed in depth, economics as social constructions and relations—crucially the normative criterion and the 'values in facts—about biophysical needs of human beings and related matter-energy transformations within a physical environment requires economics to understand *both* the relatively subjective and relatively objective epistemologies *within* ontological realism.

For instance, though the construct of society is arguably irreducible in its characteristics to individual physical humans beings within it—as society only existing through combination of multiple humans in dialectical relations between them—no society exists *without* biophysical human beings. So too do social constructions exist by virtue of their constitution by individuals their bodies and brains—though likewise we have struggled to reduce these to their entirely specific matter-energy; for instance, indicating which brain cell(s) 'contain' what an elephant is or is not. Admittedly simplified examples, though the point is to illustrate and reassert the discussion of chapter three; and to frame thermodynamic understanding of the micro level of analysis of the *system's economy* and growth or change within it.

An obvious question arises then where this leaves the concept of growth? In terms of The first law of thermodynamics the matter-energy of a system simply does not 'grow', it stays constant, thus 'growth' is more aptly referred to by transformation and redistribution as the system is in constant change rather than growth—change with *inherent* cost. In terms of the second law of thermodynamics all 'work' in the system, biological 'work'—therein anthropogenic included—ultimately decreases the amount of transformations and combinations of matter-energy possible within it; decreasing opportunities for change—though the rate of this change being indeterminate thus allowing for *limited* dynamism possible in the (re)structuring of the *system's economy*. On more meso level of analysis in the *system's economy* in terms of the bio-ecology of system Earth, as well as macro climatological relations in system Earth many thresholds of a world 'full' of anthropogenic activity have already been reached and even crossed some time ago (see Meadows et al. 1992; Meadows and Randers 2012; MEA 2005; Wackernagel and Rees 1998).

An understandable reaction would would perhaps be then to conclude that growth cannot possibly be the answer for sustainability. However, a more nuanced approach is needed in this author's opinion. An answer to the question of growth or degrowth for sustainability—in essence whether growth or degrowth would be more *economical*—cannot be confidently given unless what growth refers to is explicitly articulated (Van den Bergh 2011). However, if growth is directly or indirectly coupled to increasing anthropogenic 'work' in the system in intensity and scope, both in relation to the bioecological parts of the system, and to the matter-energy in the system, then a firm answer for the need for degrowth is inescapable (Kallis et al. 2009; Kallis 2011).

A point the above discussion on growth as transformation, redistributions—i.e. change—shows as well; for 'change' can be in any direction, a concept that is a-priori agnostic towards *all* notions of sustainability in both normative and scientific criterion. In similar fashion to how Van den Bergh (2011) argues that economic 'growth'—generally measured and indicated by Gross Domestic Product (GDP)—is too blunt a concept or tool to serve as a valid (proxy)indicator for increase in desirable orthodox economic activity, so too is growth as change too blunt to measure or (proxy)indicate desirable transformations and redistributions within and of the *system's economy*. It is only *specific certain* change that are desired aims of economics; not unidirectional and aimless change—i.e. transformation and redistribution—for the sake of change—just as 'growth' in an organism can be malignant.

5.2 Dynamism and security

Only within a system state of distribution in relation to, and between; lower security thresholds—such as biological human needs, based upon relatively non-degrading ecological foundations to satisfy these, and taking into consideration the entropic accelerating 'cost' of *all* transformations in the *system's economy*, can decoupling occur. Reconstructions of 'needs'—and 'wants' above lower security biological thresholds—can be ‘relatively’ decoupled from physical matter-energy ‘cost’ and rate of entropic decay ‘cost’. Crucially this decoupling is not possible through the absurd metaphysical framing of ‘doing more with less’—notions of ‘magical’ efficiency ratios beyond 1:1—where these are challenges to both the law of conservation of matter-energy, and the law of irreversible entropic decay. Rather, decoupling—efficiency increase of use of scarce resource towards *certain ends*—can be possible *if* it is explicitly reframed as pertaining to actively altering constructions, preferences, and choices, social organization and institutions. These relate to both anthropocentric security considerations (see Gendron 2014), and to using the *indeterminacy rate of entropic decay* to our advantage by aiming for a *certain* stability of the *system’s economy*—including managing or allowing for *certain* ecological and climatological *stable* relations *for* our benefit. Such (re)constructions are however bound to ‘violate’ current institutionalized preferences, theories, practices habits, and ‘consumption’ ‘wants’ that are both the result of, and a driving catalyst for high current high matter-energy transformation under the orthodox regime of neoclassical economics.

Thus the preceding discussion should not be misconstrued as an argument from this author for *inherently* environmentally dictated economies of supply. Rather the proposed frameworks should be understood as allowing *possibilities* of dynamism for *certain* optimality criterions in the *system’s economy* of system Earth; in other words the frameworks provided are that, frameworks for a range of possible means—in as much as the system has i.a. ecological, climatological, hydrological resilience in its parts and relations. The environment of the system—e.g. its ecological relations—dictate thresholds in the current state, and thresholds to degradation or exploitation over time, though it does not *inherently* dictate the social constructions—until for instance, certain thresholds of degradation of system relations are violated where the human species cannot survive within the system anymore.

For instance, appropriation of landmass for agriculture has ecological thresholds. However, significantly these thresholds relate to agricultural methods, practices, and intensity. Intensive industrial agriculture relates to long(er) term ecological stability of a system differently than permaculture does. Anthropogenic ‘inputs’ such as fertilizer and additional hydration of the soil, as well which crops are planted (monoculture versus multiculture) *possibly* allow for dynamism in the form and functions of anthropogenic constructed ‘economy’ upon the physical environment of the system. Furthermore, preferences for crops and infrastructure play a crucial roles in how e.g. biologically dictated needs for nutrition are satisfied. In simplified terms; how the biophysical nutritional need is satisfied often more than one option.

A *certain* dynamism is thus not only possible in the *system economy* of system Earth, but precisely where the potential for more sustainable *system economics* lies—saving us from entirely falling into an ecological determinism on the one hand, and from falling for the illusionist-as-magic tricks of the orthodox economist on the other as the latter claim to create something out of thin air. The ‘space’ in the (re)structuring and (re)organization of the ‘body’ of the anthropogenic economy within a *system’s economy*—between provisioning for current human securities such as nutrition—and allowing provisioning for future provisioning does not *inherently* frame determinism but allows principally for *certain* dynamism.

Degradation of the *system’s economy* its e.g. hydrological, ecological, and climatological relations that the anthropogenic economy—i.e. the social and the economic—are *dependent* on beyond thresholds shrink the space for dynamism. In other words, through continuing degradation in the ‘full(er)’ world context under the theories and practices of the orthodoxy—‘empty’ world (neo)classical-economics—blindly erodes its our economic foundation. A great bag of illusion tricks that orthodox economics has indeed, for us to continue in looking towards orthodox economics as the panacea for the very problems its impoverished articulation of reality and narrow utilitarianism made manifest has led to.

The author would hope the discussions of this chapter will caution the reader not to jump to a conclusion of either thermodynamic, or bioecological system determinism of the anthropogenic economy subsystem in form or function. Rather, this author hopes that the framed discussions here give an understanding that within the *system’s economy* of system Earth a degree of (in)dynamism and (in)security possible—as opposed to determinism. Likewise this author would hope the reader does not misconstrue the preceding discussions for a tradition of luddism, nor as a neo-malthusian argument with *direct* statements or emphasis on global human population numbers.

5.3 The danger of framing the anthropogenic economy as an (super)organism

Anthropogenic economic structures are sometimes framed in comparison to the biological structures of organisms; as open systems metabolising low entropy of their surroundings into higher state entropy to maintain its own relative steady-state; or to grow itself (see Avery 2012; Georgescu-Roegen 1971; Glucina and Mayumi 2010). Similarly the anthropogenic economy is sometimes referred to as a ‘superorganism’: “*The idea that single-species groups, multi-species communities, and human societies can possess the properties of single organisms*” (Wilson and Sober 1989: 337).

The pedagogical relevance of such comparisons and metaphors for interconnectedness and interdependence in the anthropogenic economy is acknowledged.

However, in such metaphors we should crucially not lose sight of the fact that unlike the biological open (sub)system—that requires to maintain their steady-state of 'life'—an anthropogenic economy is a construction of activities for *certain ends*. Its purpose is *not* to keep a *certain* structure of the economy 'alive'—we should not allow self preservation to be an applicable notion to *certain* economic structures, institutions, practices, and theories. The perceived or articulated ends of economic structures, institutions, practices, and theories are *by definition certain means*—for instance, towards satisfaction of human physiological needs, and material wealth desires. These means *can* change without 'killing' the economy—for it neither is alive nor therefore can be dead—and the ends *can* change as these structures, institutions, theories, and practices are (re)constructed—or discontinued if they do not serve the desired ends.

In organisms it is the *specific* parts and *specific* combinations, that only in their *specific* relations and combinations constitute the creature (organism) *a priori* conscious functionalism or purpose (i.e. construction thereof). The anthropocentric economy concerns *specific*, though to varying degrees implicit *conscious* purpose and functionalism: towards ends such as sustainability, pareto optimal distribution, utopian goals, survival, the good life. A system's anthropogenic economy is not a 'beast' that needs to be fed or kept 'alive' in its whole—the social and material relations constituting it can *only* be justified for the purposes or ends of our constructions.

Thus a greater variance is possible in structuring the anthropogenic economy within system Earth, as opposed to biological organisms. Restructuring of social and material relations that constitute the anthropogenic economy are crucially possible, without the protracted 'mess' of biological reconstruction through genetic mutation—evolution. Though, physically possible should not be confused here with 'ease' of social transformation. Social constructions relating to the anthropogenic economy relate to entrenched habits, socio-political accumulation patterns, power relations, and cultural preferences (see Carrier 2018; Vatn and Bromley 1994). However difficult altering these might be, it is herein that crucially lies 'half' of sustainability; its normative criterion adapting to thresholds of the scientific criterion and the dynamic space that *can* exist for it. There is simply no way around the thorny socio-political and 'moral' or normative issue of having to adjust our constructed institutions, theories, practices, relative and absolute consumption patterns, habits, and preferences to be in line with the reality of i.a. the physical micro level of analysis of the system; the bioecological meso level of the system; and macro level relations such as hydrology and climate that satisfying both our needs and want inseparably depend on. This means cutting away at the economic 'organism' if our structures, institutions, theories, practices, habits, consumption patterns and beliefs conflict with the needed stability for the desired *system's economy* of system Earth—something an organism cannot readily do without dying.

In other words, the analogy of anthropogenic economic structures and (re)structuring of the *system's economy* is argued here to be a poor analogy for the purpose of highlighting the previously discussed dynamism possible in *system economics*. The framing of anthropogenic economy as a (super)organism risks claims and reifications to its structures, institutions, theories, and practices as being framed 'necessary', 'efficient', and having 'a right to life' on their own accord—analogous to organs of the economic body. This author would argue it a twisted fallacy; and distortion of reality that hides economics the very socio-political, moral, and historical (power)relations and justifications that constitute the very same economic structures, institutions, theories, and practices.

5.4 Hidden normativity and moral economics

All economics as constructed socio-political, theories, practices, and institutions on transformations and distributions of socio-environmental scarcities are principally that; constructed and social. Thus these are *inherently* based on *certain* moral justifications, regardless of how implicit or explicitly articulated. Unless our collective—e.g. consensus based—normative criterion for optimal distribution is increasing 'wealth', 'welfare', and socio-political power disparities in distribution; *and* a degrading 'environment' resulting in increasing negatives—costs—that will be felt proportionally harder by those with relatively low 'wealth', 'welfare', and socio-political power, *only then* is orthodox economic theory and practice as discussed 'valid' means towards *that* normative criterion of sustainability—herein the scientific criterion would inherently a self-degrading system. If this does not meet our collective—e.g. consensus based—normative criterion in the double criterion sustainability model, then we continue to allow orthodox neoclassical economics to be presented as 'valid' scientific means of restructuring and maintaining our *system's economy* of system Earth.

Supposed externalities and system degradation correlating with orthodox economic theory and practices are no aberrations but structural features of its theories and practices. No longer can orthodox economics be allowed to hide its ontological and epistemological assumptions and claims—presenting a *certain* rational, a *certain* too narrow view on utility, *hidden* socio-political justifications and moral relations, behind a language of supposed objectivity and neutrality dressed up in positivist methodology as a 'science'.

Social and environmental informational deficits in system understanding in orthodox economic theory and practice are thus not aberrations of an otherwise perfect method for altering the *system's economy* towards a normative criterion of optimality by scientifically valid means. Rather, juxtaposed against dialectical relations on the *system's economy*—such as ecological, hydrological, climatological, and (non orthodox economic) social relations—these informational deficits in neoclassical orthodox economics are structurally *inherent* to its ontological assumptions, epistemological claims, and methodological choices—thus a logical result of its construction of, and workings assumptions on assumption of an impoverished reality. For effective economics transformations of the *system's economy* towards a normative optimality criterion the productivity or efficiency of transformations (beyond a full world context) lie in recoupling or re-embedding economics into its constitutive socio-environmental reality—correcting cost and benefit awareness and articulation. Thus efficiency and productivity 'increase' from a *system economics* perspective are only possible to achieve through social reconstruction of needs and wants; i.e. 'doing more *of similar services* more with less'.

The undeniable reality is that economics *is* about social relations and (socio-environmental) redistribution by definition through social relations. No matter how well hidden away within an language of objectification of value, supposed neutrality, and cost-shifting practices across distance and time; *all* economics is moral economics of redistribution (see Sayer 2015; Knox-Hayes 2015). Judgement and normativity are not optional (see chapter three), but are in fact impossible to avoid in *all* economics—they can merely be hidden in implicit value positions and behind supposed objective positivist methodologies in orthodox economic theory and practice (Myrdal 1978; Spash 2012a). Orthodox economics' positivist methodology cannot solely carry—i.e. justify, legitimate, and validate—its position as *the* dominant 'scientific' approach, and that towards which socio-political debates and practice look towards for effectively restructuring the *system's economy* of system Earth towards sustainable system state(s).

Concluding Remarks

This thesis started with the question on whether economics versus sustainability is a relationship of paradox or contradiction. The abstract consensus definition of sustainability has been rejected for academic use; being founded on and legitimizing both prior power relations and continuing the hegemony of neoclassical orthodox economic theories, practices, and institutions in its abstract definition and operationalizations. Instead a meta-framework has been suggested, framed by *both* a normative criterion *and* a scientific criterion. Thus all goals are reframed as a *certain* construction of sustainability pertaining to a *desirable* system state that can be critically assessed in whether—and how—these are *possible* to develop towards, and maintained over an envisioned long(er) timescale. This approach has allowed economics to be reframed as scientifically possible means towards a these *certain* sustainability constructions of ends or goals—such as a 'Pareto optimal' distribution in relation to 'wealth', 'welfare', or 'well-being'.

Thus the oppositional *all* economics versus sustainability framing *is* principally a paradoxical relationship, and not one of contradiction. However, *certain* economics are contradictory to *certain* normative criterion in sustainability—as *certain* economics as *means* can be contradictory to *certain desired ends*, in addition to the standard question of validity of *certain* economics its understanding and accounting for reality. Thereafter the discussion turned to the three dimensional framing of sustainability in juxtaposition to ecological and sociological understanding of 'the environment' with a focus on dependencies of humans on *our* environment. This discussion highlighted a crucial difference between orthodox and heterodox approaches in what is considered as economic—i.e. as 'internal' to economy and what is considered 'external'. This difference has been shown to become increasingly problematic when the 'external' is attempted to be made 'internal' in an increasing full(er) world context of i.a. ecological overshoot and degradation—highlighting a dialectical versus antimorphic clash underlying academic and socio-political debates in sustainability resulting in miscalculated costs and benefits.

A philosophy of science meta-framework it thus proposed to correct for this clash, to allow for examination of the paradoxes sprouting from (attempts at) multi- and interdisciplinary approaches to sustainability and economics—evidenced by the dominant socio-political and academic debates—and to allow for more accurate cost and benefit judgements in economics (new form) in line with the proposed meta-framework for sustainability. This framework is proposed to be characterized by a presupposition of a multi-leveled ontology; constructed through a structured critical pluralism of epistemologies that are relatively incommensurable to each other. Neoclassical orthodox economics' *implicit* ontological presuppositions and epistemological claims are discussed and in relation to this framework criticized—leading to proposing an approach this author indicates by *system economics*; wherein economics its position is re-embedded within the social relations it is constituted by, and in turn within the environment(s) that the social relations are *dependent partials* of. Framing hierarchically embedded though irreducible relations of a *system's economy*. The concept of complexity or novelty by combination is emphasized—where relations between parts on one analytical level are understood as forming new parts on 'higher' analytical levels *through their irreducible relations*; thus likewise parts identified on one analytical level being constituted by, though irreducible to parts on 'lower' analytical levels. The proposed *system economics* thus necessitating *critical pluralism* and a degree of *incommensurability* in accounting for a *system's economy*—dependency and embeddedness on the one hand; dynamism, novelty by combination, and irreducibility on the other.

Using this meta-framework for *system economics* in combination with the double-criterion framework for sustainability the thesis cautiously concludes that the relationship between sustainability and (the neoclassical orthodox) economics is one of *actual* contradiction, as its understanding of the system economy of system Earth, and delineations therein are in the full(er) world context—marked by i.a. ecological overshoot and climate disruptions—*inherently* and self-defeatingly incomplete and invalid. The socio-environmental cost-shifting practices that continue to be the core of its focus—seemingly having taken on a life of their own through belief in the magic tricks of economic growth and efficiency paradigms—do not work when the system's thresholds have long ago been reached and crossed.

Through its assumptions of an economic reality that is divorced from a social one and an environmental one, and neoclassical orthodox economics' often *intentional* spatial and temporal distancing—i.e. socio-environmental cost-shifting—it has an invalid relationship to both supposed normative criterion and scientific criterion in sustainability. Neoclassical orthodox economics, in acting upon this impoverished reality through theory and practice, logically has led to short fallings in accounting and articulating *validly* socio-environmental costs and benefits of transforming the relatively closed system Earth—the macro *system economy* for humans. Thus having led to unsustainable structures, institutions, practices justified by its theories that now form a primary contradiction to increasing sustainability. In other words, the simple truth is that there is no longer somewhere we can effectively shift these costs to, other than to *our own* future selves, or our neighbors with whom we already have social relations and power relations.

We require a *management of our oikos* (economics) for how we *can* and *cannot* transform or develop our *oikos*. An economics that serves human goals or ends of the *system economy* of system Earth; not an economics to which human goals or ends serve towards, or works only towards the goals or ends of a disproportionately better off minority within system earth at the expense of the majority—unless we collectively frame this as our desired, sustainable, or pareto-optimal system state.

The colloquial saying of 'the elephant in the room' refers to an important subject that is commonly known but avoided, ignored, and wished away—in any case a subject not addressed or discussed. This author proposed that this saying remains apt to the discussion of sustainability and economics. In fact, this author proposes that a better analogy would be that it concerns not a singular elephant, but a whole herd of elephants, most of which are even not allowed into the metaphorical room yet—nor would they fit into the current 'room' framed by the dominant academic and socio-political debates on sustainability and economics. The stampeding herd of 'elephants' outside of the 'room' that symbolises the major sustainability and economics debate(s) need to be recognized and addressed as opposed to the current general agnosticism or atheism towards their very existence; not just in academics but also crucially in general socio-political debate(s) that continues to look towards neoclassical orthodox economics as the panacea for—sustainable—'development'.

References

Adams, Douglas. 2017. *The Hitchhiker's Guide to the Galaxy Omnibus: A Trilogy in Four Parts.* London: Pan Macmillan.

Adams, William M. 2014. 'The Value of Valuing Nature.' *Science* 346-6209: 549-551.

Adkisson, Richard V. 2009. 'The Economy as an Open System: an Institutionalist Framework for Economic Development.' In *Institutional Analysis and Praxis*, edited by Natarajan, Tara, Wolfram Elsner, and Scott Fullwiler, 25-38. New York, NY: Springer.

Appleton, Albert F. 2006. 'Sustainability: A Practitioner's Reflection' *Technology in Society* 28-1: 3-18.

Armsworth, Paul R., Kai M. A. Chan, Gretchen C. Daily, Paul R. Ehrlich, Claire Kremen, Taylor H. Ricketts, and M. A. Sanjayan. 2007. 'Ecosystem‐Service Science and the Way Forward for Conservation.' *Conservation Biology* 21-6: 1383-1384.

Archer, Margaret, Claire Decoteau, Philip Gorski, Daniel Little, Douglas Porpora, Timothy Rutzou, Christian Smith, George Steinmetz, and Frederic Vandenberghe. 2016. 'What is Critical Realism?' *Perspectives* 38-2: 4-9.

Avery, John S. 2012. Entropy and Economics. *CADMUS* 1-4: 166-179.

Bartelmus, Peter. 2013. 'The Future We Want: Green Growth or Sustainable Development?' Environmental Development 7-1: 165-170.

Bartlett, Albert A., 1994. 'Reflections on Sustainability, Population Growth, and the Environment.' *Population and Environment: A Journal of Interdisciplinary Studies* 16-1: 5-35.

Baumgärtner, Stefan, and Martin Quaas. 2010. 'What is Sustainability Economics?' *Ecological Economics* 69: 445-450.

Black, John, Nigar Hashimzade, and Gareth Myles. 2012. 'A Dictionary of Economics.' Oxford University Press, 2012. Accessed 2017-06-27. http://www.oxfordreference.com/view/10.1093/acref/9780199696321.001.0001/acref-9780199696321-e-938.

Blunden, Andy. 2009. 'Critical Realism and Reality.' Accessed 11-06-2017. http://home.mira.net/~andy/works/bhaskar.htm.

Boulding, Kenneth E. 1966. 'The Economics of the Coming Spaceship Earth.' In: *Environmental Quality in a Growing Economy*, edited by: Henry Jarrett, 3-14. Baltimore: Johns Hopkins University Press.

Brown, James R., and Yiftach Fehige. 2017. 'Thought Experiments', The Stanford Encyclopedia of Philosophy (Summer 2017 Edition),' edited by Edward N. Zalta. Accessed 19-06-2017. https://plato.stanford.edu/archives/sum2017/entries/thought-experiment/.

Buch-Hansen, Hubert. 2014. 'Capitalist Diversity and De-Growth Trajectories to Steady-State Economies' *Ecological Economics* 106: 167-173.

Caldwell, Bruce. 1980. 'Positivist Philosophy of Science and the Methodology of Economics.' *Journal of Economic Issues* 14: 53-75.

Carrier, James G. 2018. 'Moral Economy: What's in a Name.' *Anthropological Theory* 18-1: 18-35.

Christen, Marius, and Stephan Schmidt. 2012. 'A Formal Framework for Conceptions of Sustainability – a Theoretical Contribution to the Discourse in Sustainable Development.' *Sustainable Development* 20-1: 400–410.

Clark, Helen. 2013. 'What Does Rio+20 Mean for Sustainable Development?' *Development* 56-1: 16-23.

Cole, H.S.D., Christopher Freeman, Marie Jahoda, and K.L.R. Pavitt (Eds.). 1973. *Models of doom: A Critique of Limits to Growth.* New York City: Universe Books.

Connelly, Steve. 2007. 'Mapping Sustainable Development as a Contested Concept' *Local Environment* 12-3: 259–278.

Costanza, Robert. 2012. 'The Value of Natural and Social Capital in Our Current Full World and in a Sustainable and Desirable Future.' In *Sustainability Science: The Emerging Paradigm and the Urban Environment*, edited by Weinstein, Michael P., and R. Eugene Turner, 99-109. New York: Springer.

Daly, Herman E. 1992a. 'Comment- Is the Entropy Law Relevant to the Economics of Natural Resource Scarcity?' *Journal of Environmental Economics and Management* 23: 91-95.

Daly, Herman E. 1992b. 'From Empty-World Economics to Full-World Economics: Recognizing an Historical Turning Point in Economic Development.' In: *Population, Technology and Lifestyle,* edited by: Robert Goodland, Herman E. Daly, and Salah El Serafy, 23-37. Washington D.C.: Island Press.

Daly, Herman E. 2015. ‘Economics for a Full World.’ *The Great Transition Initiative*. Accessed 01-10-2016 http://www.greattransition.org/publication/economics-for-a-full-world.

Dawe, Neil K., and Kenneth L. Ryan. 2003. ‘The Faulty Three-Legged-Stool Model of Sustainable Development.’ *Conservation Biology* 17-5: 1458-1460.

Dobson, Andrew. 2012. *Green Political Thought*. Oxford, UK: Routledge.

Dow, Sheila .C. 2007. ‘Variety of Methodological Approach in Economics.’ *Journal of Economic Surveys* 21-3: 447-465.

Drews, Stefan, and Miklós Antal. 2016. ‘Degrowth: A “missile word” that backfires?’ *Ecological Economics* 126: 182-187.

Egelston, Anne E. 2012. *Sustainable Development: a History.* London: Springer Science, and Business Media.

Ellwood, Sheila, and Margaret Greenwood. 2016 'Accounting for Heritage Assets: Does Measuring Economic Value ‘Kill the Cat’?' *Critical Perspectives on Accounting* 38: 1-13.

Escobar Arturo. 1995. *Encountering Development: the Making and Unmaking of the Third World.* Princeton, New Jersey: Princeton University Press.

Escobar, Arturo. 2015. 'Degrowth, Postdevelopment, and Transitions: A Preliminary Conversation' *Sustainability Science* 10-3: 451-462.

Fricker, Alan. 1998. 'Measuring up to Sustainability' *Futures* 30-4: 367–375.

Fergus, Andrew H.T., and Julie I.A. Rowney. 2005. 'Sustainable Development: Lost Meaning and Opportunity?' *Journal of Business Ethics* 60-1: 17–27.

Ferguson, Peter. 2015. ‘The Green Economy Agenda: Business as Usual or Transformative Discourse?’ *Environmental Politics* 24-1: 17-37.

Ferguson, Peter. 2016. ‘Liberalism and Economic Growth: A Theoretical Exploration’ *Environmental Values* 25-5: 593-619.

Fisher, Brendan, R. Kerry Turner, and Paul Morling. 2009. ‘Defining and Classifying Ecosystem Services for Decision Making.’ *Ecological Economics* 68-3: 643-653.

Fisk, David. 2011 'Thermodynamics on Main Street: When Entropy Really Counts in Economics' *Ecological Economics* 70-11: 1931-1936.

Funtowicz, Silvio O., and Jerome R. Ravetz. 1994. ‘The Worth of a Songbird: Ecological Economics as a Post-normal Science.’ *Ecological Economics* 10-3 197-207.

Gendron, Corinne. 2014. 'Beyond Environmental and Ecological Economics: Proposal for an Economic Sociology of the Environment.' *Ecological economics* 105: 240-253.

Georgescu-Roegen, Nicholas. 1971. *The Entropy Law and the Economic Process*. Cambridge, Massachusetts: Harvard University Press.

Glucina, Mark David, and Kozo Mayumi. 2010. 'Connecting Thermodynamics and Economics Well-lit Roads and Burned Bridges' *Annals of the New York Academy of Sciences* 1185:11–29.

Gómez-Baggethun, Erik, Rudolf de Groot, Pedro L. Lomas, and Carlos Montes. 2010. ‘The History of Ecosystem Services in Economic Theory and Practice: From early Notions to Markets and Payment Schemes.’ *Ecological Economics* 69-6: 1209-1218.

Gómez-Baggethun, Erik, and Manuel Ruiz-Pérez. 2011. ‘Economic Valuation and the Commodification of Ecosystem Services.’ *Progress in Physical Geography* 35-5: 613-628.

Harlow, John, Aaron Golub, and Braden Allenby (2011) 'A Review of Utopian Themes in Sustainable Development Discourse' *Sustainable Development* 21-1: 270–280.

Hens, Luc, and Bhaskar Nath. 2003. ‘The Johannesburg Conference.’ *Environment, Development and Sustainability* 5.1-2): 7-39.

Hugé, Jean, Tom Waas, Farid Dahdouh-Guebas, Nico Koedam, and Thomas Block. 2013. 'A Discourse-Analytical Perspective on Sustainability Assessment: Interpreting Sustainable Development in Practice' *Sustainable Science* 8-1: 187–198.

Kagan, Sacha. 2010. ‘Cultures of Sustainability and the Aesthetics of the Pattern that Connects." *Futures* 42-10: 1094-1101.

Kallis, Giorgos. 2011. ‘In Defence of Degrowth’ *Ecological Economics* 70: 873-880.

Kallis, Giorgos, and Hug March. 2014. 'Imaginaries of Hope: The Utopianism of Degrowth.' *Annals of the Association of American Geographers* 105-2: 360-368.

Kallis, Giorgos, Erik Gómez-Baggethun, and Christos Zografos. 2013. ‘To Value or not to Value? That is not the Question.’ *Ecological Economics* 94: 97-105.

Kallis, Giorgos, Joan Martinez-Alier, and Richard B. Norgaard. 2009. 'Paper assets, real debts: An Ecological-Economic Exploration of the Global Economic Crisis.' *Critical Perspectives on International Business* 5-1/2: 14-25.
Kapp, K. WIlliam. 1976. 'The Open-System Character of the Economy and its Implications.' In *Economics in the Future*, edited by: Dopfer, Kurt, 90-105. London: Palgrave,
Kemp, René, and Pim Martens 2007. 'Sustainable Development: How to Manage Something that is Subjective and Never can be Achieved?' *Sustainability: Science, Practice, and Policy* 3-2: 5-14.
Kovalev, Andrey V. 2016. 'Misuse of Thermodynamic Entropy in Economics' *Energy* 100: 129-136.
Knox-Hayes, Janelle. 2015 'Towards a Moral Socio-Environmental Economy: A Reconsideration of Values' *Geoforum* 65: 297-300.
Kronenberg, Jakub, and Klaus Hubacek. 2016. 'From Poverty Trap to Ecosystem Service Curse.' *Sustainability Science* 11-6: 903-907.
Lehtonen, Markku. 2004. 'The Environmental–Social Interface of Sustainable Development: Capabilities, Social Capital, Institutions.' *Ecological Economics* 49-2: 199-214.
Maniates, Michael. 2013. 'Teaching for turbulence.' in *State of the World 2013*, 255-268. Washington D.C.: Island Press.
Martínez-Alier, Joan. 2002. *The Environmentalism of the Poor: A Study of Ecological Conflicts and Valuation*. Cheltenham: Edward Elgar Publishing.
Martínez-Alier Joan. 2012. 'Social Metabolism, Environmental Cost-Shifting and Valuation Languages.' In *Towards an Integrated Paradigm in Heterodox Economics*, edited by Julien-François Gerber and Rolf Steppacher, 94-110. London: Palgrave Macmillan.
Meadows, Dennis L., Donella H. Meadows, Jørgen Randers, and William W. Behrens III. 1972. *The Limits to Growth: A Report to The Club of Rome.* New York: Universe Books.
Meadows, Donella H., Dennis L. Meadows, and Jørgen Randers. 1992. *Beyond the Limits: Confronting Global Collapse, Envisioning a Sustainable Future.* Post Mills, Virginia: Chelsea Green Publishing.
Meadows, Dennis, and Jørgan Randers. 2012. *The Limits to Growth: The 30-year Update.* London: Routledge.
Merriam-Webster. 2018. 'Economics.' Accessed. 25-04-2018. https://www.merriam-webster.com/dictionary/economics.
Millennium Ecosystem Assessment (MEA), 2005. *Ecosystems and Human Well-being: Synthesis.* Washington D.C.: Island Press.
Moses, Jonathon, and Torbjørn Knutsen. 2012. *Ways of Knowing: Competing Methodologies in Social and Political Research*. New York: Palgrave Macmillan.
Myrdal, Gunnar. 1978. 'Institutional Economics.' *Journal of Economic Issues* 12: 771–783.
Peterson, Markus J., Damon M. Hall, Andrea M. Feldpaush-Parker, and Tarla R. Peterson. 2010. 'Obscuring Ecosystem Function with Application of the Ecosystem Services Concept.' *Conservation Biology* 24-1: 113-119.
Rees, William. 2015. 'Economics vs. the Economy' *Great Transition Initiative*. Accessed 2017-06-27. https://www.greattransition.org/publication/economics-vs-the-economy.
Redclift, Michael. 2005. 'Sustainable Development (1987–2005): An Oxymoron Comes of Age' *Sustainable Development* 13: 212–227.
Rutzou, Timothy. 2016. 'What are the Criteria of Judgmental Rationality?' Accessed 21-03-2017 http://criticalrealismnetwork.org/2016/07/13/rationality/.
Sayer, Andrew. 2015 'Time for Moral Economy' *Geoforum* 65: 291-293.
Saxe, Godfrey J. 2017 [1872]. 'The poems of John Godfrey Saxe: The Blind Men and the Elephant.' Accessed 11-06-2017. https://en.wikisource.org/wiki/The_poems_of_John_Godfrey_Saxe/The_Blind_Men_and_the_Elephant.
Schellnhuber, Hans J., Katja Frieler, and Pavel Kabat. 2014 'The Elephant, the Blind, and the ISI-MIP.' *Proceedings of the National Academy of Sciences* 111-9: 3225-322.
Schrödinger, Erwin. 1945. *What is Life?* New York: Macmillan Company.
Scott, James C. 1998. *Seeing like a state: How Certain Schemes to Improve the Human Condition Have Failed.* Yale University Press.
Söderbaum, Peter. 2007. 'Issues of Paradigm, Ideology and Democracy in Sustainability Assessment.' *Ecological Economics* 60-3: 613-626.
Söderbaum, Peter. 2011. 'Sustainability Economics as a Contested Concept.' *Ecological Economics* 70-6:

1019–1020.
Söderbaum, Peter. 2014. 'The Role of Economics and Democracy in Institutional Change for Sustainability.' *Sustainability* 6: 2755-2765.
Söderbaum, Peter. 2015. 'Varieties of Ecological Economics: Do We Need a More Open and Radical Version of Ecological Economics?' *Ecological Economics* 119: 420-423.
Spash, Clive L. 2008. ‘How Much is that Ecosystem in the Window? The One with the Bio-diverse Trail.’ *Environmental Values* 17-2: 259-284.
Spash, Clive L. 2012a ‘New Foundations for Ecological Economics.’ *Ecological Economics* 77: 36-47.
Spash, Clive L. 2012b ‘Green Economy, Red Herring’ *Environmental Values* 21-2: 95-99.
Spencer, Neville. 2017 ‘On the Significance of Distinguishing Ontology and Epistemology.’ Accessed 11-06-2017. http://ethicalpolitics.org/seminars/neville.htm.
Tacconi, Luca. 1998. ‘Scientific Methodology for Ecological Economics.’ *Ecological Economics* 27: 91-105.
The Economist. 2017. ‘Economics A-Z terms beginning with E - Economics.’ Accessed 2017-06-27. http://www.economist.com/economics-a-to-z/e#node-21529558.
Trimmer, John D. 1980. 'The Present Situation in Quantum Mechanics: A Translation of Schrödinger's "Cat Paradox".' *Proceedings of the American Philosophical Society* 124-5: 323-338.
United Nations Conference on Sustainable Development (UNCSD). 2012. ‘Resolution Adopted by the General Assembly on 27 July 2012 - The Future We Want.’ Accessed on 2014-04-12. http://www.un.org/en/ga/search/view_doc.asp?symbol=%20A/RES/66/288.
Van den Bergh, Jeroen C.J.M. 2011. ‘A Criticism of “Degrowth” and a Plea for “A-Growth”.’ *Ecological Economics* 70: 881-890.
Van den Bergh, Jeroen C.J.M., and Giorgos Kallis. 2013. 'Growth, A-Growth or Degrowth to Stay within Planetary Boundaries?' *Journal of Economic Issues* 46-4: 909-920
Vatn, Arild, and Daniel W. Bromley. 1994. ‘Choices Without Prices Without Apologies.’ *Journal of Environmental Economics and Management* 26-2: 129-148.
Victor, Peter A. 2010. ‘Ecological Economics and Growth.’ *Annals of the New York Academy of Sciences* 1185: 237-245.
Vitousek, Peter M., Paul R. Ehrlich, Anne H. Ehrlich, and Pamela A. Matson. 1986. ‘Human Appropriation of the Products of Photosynthesis.’ *BioScience* 36-6: 368-373.
Waas, Tom, Jean Hugé, Aviel Verbruggen, and Tarah Wright. 2011. 'Sustainable Development: A Bird's Eye View.' *Sustainability* 3-1: 1637-1661.
Wackernagel, Mathis, William Rees. 1998. *Our Ecological Footprint: Reducing Human Impact on the Earth.* Gabriola Island, British Columbia: New Society Publishers
Wiedmann, Thomas O., Heinz Schandl, Manfred Lenzen, Daniel Moran, Sangwon Suh, James West, and Keiichiro Kanemoto. 2015. ‘The Material Footprint of Nations.’ *Proceedings of the National Academy of Sciences* 112-20: 6271-6276.
Wiersum, K. Freerk. 1995. '200 years of sustainability in forestry: Lessons from history.' *Environmental Management* 19-3: 321-329.
Wiesmeth, Hans. 2012. *Environmental Economics: Theory and Policy in Equilibrium*. New York: Springer Science, and Business Media.
Wilson, David Sloan, and Elliott Sober. 1989. ‘Reviving the Superorganism.’ *Journal of theoretical Biology* 136-3: 337-356.
Woodruff, David S. 2012. ‘A Tale of Two Planets: Biodiversity and Environmental Sustainability Before and After Rio+ 20.’ *The Journal of Environment, and Development* 21-1: 15-18.
World Commission on Environment and Development (WCED). 1987. *Our Common Future.* New York: Oxford University Press.
Zencey, Eric. 2013. ‘Energy as Master Resource.’ In *State of the World 2013*, 73-83. Washington D.C.: Island Press.