

ARTIGO

ENVIRONMENTAL ECONOMICS AND NATURAL RESOURCES VERSUS ECOLOGICAL ECONOMICS**ECONOMIA AMBIENTAL E RECURSOS NATURAIS VERSUS ECONOMIA ECOLÓGICA**PAUL COONEY¹**RESUMO**

Esse artigo apresenta uma comparação das duas abordagens relacionado ao estudo da economia e o meio ambiente, a saber, Economia Ambiental e Recursos Naturais e Economia Ecológica. A primeira foi a incorporação no campo do Meio Ambiente na Economia Neoclássica e é associada com uma abordagem multidisciplinar. A segunda, Economia Ecológica, adota uma abordagem interdisciplinar entre economia, e campos como biologia, geologia, geografia, sociologia, e ciência ambiental.

Palavras-chave: Economia Ambiental; Recursos Naturais; Economia Ecológica

ABSTRACT

This article presents a comparison of the two major approaches related to the study of economics and the environment, namely Environmental and Resource Economics and Ecological Economics. The first one was the incorporation of the field of the Environment into Neoclassical Economics and is associated with a multi-disciplinary approach. The second one, Ecological Economics, adopts an interdisciplinary approach between economics, and fields such as biology, geology, geography, sociology, and environmental science.

Keywords: Environmental Economics; Natural Resources; Ecological Economics

1 INTRODUÇÃO

This paper begins with a brief description and history of the two approaches that examine the interactions of economics and the environment, namely, Environmental and Resource Economics (ERE) and Ecological Economic (EE). The second section presents the comparison of these approaches, emphasizing differences in terms of method and theory. The third section identifies the 7 main points of difference which will be examined in making these comparisons between perspectives. The most salient topics include open and closed systems, multidisciplinary vs interdisciplinarity, methodological pluralism, multicriteria analysis and weak and strong versions of

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sustainability. Finally, in the Conclusions section presents an overall assessment.

HISTORY OF ENVIRONMENTAL AND RESOURCE ECONOMICS

In general, the establishment of “environmental economics” or “environmental and resource economics” was during the 1960s, as evidenced by the use of the term in articles and book titles, and the establishment of environmental economics journals, conferences and professional associations subsequently. Some argue that it began much before that, consider Agnar Sandmo (2015), mentioning authors such as Pigou, who is associated with the term externalities or the problem of population, as in Malthus. It was after the Second World War when the US government focused on the issue of natural resource scarcity and initiated studies in this field. The general view is that the field of “environmental economics and natural resources” became established the 1960s.

Ropke (2004) argues that ERE became associated with “the three functions of the environment for the economy that later appeared in introductions to environmental and resource economics: (1) resources for production; (2) assimilative capacity to absorb pollution; (3) direct utility related to the enjoyment of nature (amenity value)” (Ropke, 2004, p. 300). The practical reality is that this field or approach, despite emphasizing the importance of environmental issues, tended to be more concerned with finding ways of making profit from the exploitation of natural resources.

HISTORY OF ECOLOGICAL ECONOMICS

The following is a description of the early period of Ecological Economics by van den Bergh (2001): “The field known as “Ecological Economics” (EE) was founded at the end of the 1980s. It immediately attracted a large number of researchers from various disciplinary backgrounds that were involved in the study of environmental issues. ... The core of EE can be associated with the goal of sustainable development... the view that the economy is a subsystem of a larger local and global ecosystem which sets limits to the physical growth of the economy; and a methodological approach based on the use of physical (material, energy, chemical, biological) indicators and comprehensive systems analysis” (van den Bergh, 2001, p. 13).

As discussed below EE corresponds to an interdisciplinary approach to the intersection of economics and the environment, clearly distinct from the approach of environmental and resource economics (ERE). Given the inadequacy of the

methodology and theoretical analysis of ERE numerous economists, environmentalists, biologists, ecologists and other researchers in the fields related to the environment have sought and been open to the approach associated with ecological economics.

According to van den Bergh: "The economists K.E. Boulding (1966), H.E. Daly (1977) and N. Georgescu-Roegen (1971) and the ecologists C.S. Holling (1973) and H.T. Odum (1971) are usually considered to be the intellectual founders and antecedents of EE" (van den Bergh, 2001, p. 14). The growing importance of ecology and environmental issues, had to do with the historical context of the early 1970s in the US: the existence of the environmental movement, the establishment of the EPA (Environmental Protection Agency), Earth Day, the energy crisis, the concerns of growth, population and environmental problems ranging from acid rain, the ozone layer, Three Mile Island, Chernobyl, etc.

The field of ecological economics is often identified as having arrived with the Brundtland Conference of 1987, which is associated with introducing a rather weak version of the concept of Sustainable Development², although the field extends way beyond just this concept, especially now in the 2020s. This new discipline within Economics is recognized for its support for methodological pluralism and an interdisciplinary approach, dedicated to analyzing the interaction between economic and ecological processes, but with a much broader foundation than ERE.

2 COMPARISON OF APPROACHES IN TERMS OF METHOD AND THEORY

This article concentrates on a comparison of the two major approaches to the study of economics and the environment, namely Environmental and Resource Economics (ERE) and Ecological Economics (EE). The first one was the incorporation of the field of the Environment into Neoclassical Economics and is associated with a multi-disciplinary approach. The second one, Ecological Economics, adopts an interdisciplinary approach, if not transdisciplinary,³ between economics, biology, geography, sociology, and environmental science, and other related disciplines.

2. The Brundtland Conference was a United Nations Conference held in 1987 to address environmental and economic issues, and it is associated with introducing the concept of sustainable development, though a rather conservative version not even mentioning the environment.

3. There are several different interpretations of these terms, but the meaning of these two terms used in this chapter is as follows: multidisciplinary combines analysis from two or more disciplines, but only alongside one another, while interdisciplinary will produce more of a synergy and integrates multiple disciplines, while transdisciplinary is actually achieving scientific advances which transcend the boundaries of any individual field.

Both clearly have strong roots in Economics, though clearly Ecological Economics has a much broader foundation.

In addition to the contrast of ERE being multidisciplinary while EE is interdisciplinary, several key points of difference both methodologically and theoretically, are: methodological pluralism; open versus closed systems; the debate between strictly monetary criteria in the case of ERE and multicriteria in the case of EE; the position regarding weak or strong sustainability, etc. Of increasing relevance in debates is the mainstream concept of Natural Capital, advocated by ERE and used as a way to justify destruction of nature as long as fixed and monetary capital is sufficiently available. The dominant view within EE, but not unanimous, is that nature could be seen as potential capital, but it is absolutely wrong to refer to a pristine forest as capital. All of these points of difference will be elaborated upon in the coming sections.

A. CONTRAST BETWEEN ERE AND EE AND DIFFERENT PERSPECTIVES WITHIN EE

The initial aim of this article is the pursuit of a comparison of Environmental and Resource Economics (ERE) and Ecological Economics (EE). Some of the currently more prominent authors, such as João Martínez Alier or Clive Spash appear to be the cutting edge of the field and the analysis associated with EE, is dynamically changing. Perhaps more importantly, is the need to identify the tendencies which are becoming more dominant and showing greater potential for ecological economics and the environment.

As the development of this paper advanced the decision to identify the main points for comparison became difficult, given the different perspectives and changes over time, especially within EE. Although the neoclassical perspective is still present in the field of EE and may dominate the journal *Ecological Economics*, the areas of change, and in my opinion, those with greater relevance, are those of the critical and radical perspectives within EE. The conservative view tends to reflect the discourse prevalent in the Global North and therefore more influential in the seats of power. However, the dominant views from the Global South tend to be more critical, if not radical, given the greater burden of ecological crises and problems, also related to social inequalities globally.

DIFFERENT PERSPECTIVES WITHIN ECOLOGICAL ECONOMICS

Before elaborating upon which themes will be examined for comparing ERE with EE, a further presentation of different approaches within EE will be considered. This is following the distinctions within Ecological Economics that Barkin, Fuente and Tagle presented in their 2012 article. As Barkin et al argue, “Ecological Economics has achieved a confluence of research from various fields, which has brought about the development of different versions of EE, depending upon their relationship with the capitalist economic rationality or free market” (BARKIN et. al., 2012, p. 4). According to them, one can categorize three approaches within Ecological Economics: conservative, critical and radical. The argument for these three versions first appeared in an article by Fuente, one of the co-authors (FUENTE, 2008)⁴, and it seems that the argument was further refined or detailed in the later article. In brief, the three versions within EE are described below with a few of the main names, that are associated with each perspective.

The conservative perspective includes the main founders of Ecological Economics, such as Nicolas Georgescu Roegen, Herman Daly and Robert Costanza. They correspond to this perspective given their tendency to still work with the majority of the neoclassical foundation and tools, in spite of their points of difference with ERE. Additional authors of note, included in this perspective are: Gowdy and Erikson, van den Bergh, E. De Groot, Norgaard, and Boulding. BFT argue that “This version does not recognize the relation between power, the capitalist economic rationality and unsustainability” (BFT, 2012, p. 4). They also argue that this perspective does not recognize the role of social conflict or class struggle. Making use of these three perspectives within ecological economics, seems helpful in identifying important differences which deserve attention in comparing different perspectives⁵.

The critical perspective, refers to Martinez Alier and his school, including Gomez-Baggethun, and other authors coming from the heterodox economic perspectives, be it Keynesian, Neo-Ricardian, evolutionary economics, institutionalists, etc. They are both critical of the neoclassical perspective, market economic rationality and unsustainability. They argue that implementation of only market solutions will not promote a solution to the environmental crisis and show that an inadequate

4. In the earlier article by Fuente (2008, p. 90), the three categories are listed as conservative, critical and EE heterodox or radical, instead of just radical. The presentation or content corresponding to the three perspectives is quite similar, though there is greater elaboration upon them in the later article with Barkin and Tagle, hereafter referred to as BFT (2012).

5. It is worth noting that the conservative view dominates the journal of the International Society of *Ecological Economics* (ISEE), namely, *Ecological Economics*, whose first Editor in chief was Robert Costanza. Unfortunately, the journal has come to include many ERE economists, and many are more conservative than Costanza.

incorporation of methodological pluralism could come to worsen or deepen the social and environmental crisis. According to BFT, they include social ecology, in particular Clive Spash in this critical perspective.

The radical perspective includes radical political economy, radical political ecology and radical ecological economics, much of which is overlapping and tends to be marxist. This version argues for the need to carry out a break or rupture from the neoclassical economic rationality discourse, which defends methodological individualism and unsustainability, and at best a weak version of sustainability, and also capitalist accumulation, without naming it as such. The main radical authors identified by BFT(2012) include: John Bellamy Foster, Paul Burkett, James O'Connor, Joel Kovel, Elmar Altvater, Enrique Leff, H.T. Odum, Alf Hornburg, among others. It seems appropriate to include Clive Spash (2017) and the social ecology school as part of the radical perspective as they see the need to go beyond a capitalist growth paradigm in order to resolve and address major ecological crises and problems we currently face.

B. MAIN POINTS OF DIFFERENCE BETWEEN ERE AND EE

Depending on one's perspective, be it ERE, EE or one of the three perspectives identified within EE, the main issues or themes of relevance for comparison will vary. For example, according to Gowdy and Erickson (2005), "the major tenets of ecological economics are value pluralism, methodological pluralism and multi-criteria policy assessment" (GOWDY and ERICKSON, 2005, p. 207), which tend to be common points of difference with ERE. Another important article contrasting ecological economics and environmental and resource economics is that of van den Bergh in 2001. Though he considers himself an ecological economist, based on his analysis he is still working primarily from a neoclassical perspective, though critical of certain elements. Therefore, he corresponds to the conservative perspective within EE, as identified above. He argues that "The core of ERE is the theory of (negative) externalities or external costs", and in contrast he argues that "EE has chosen sustainable development as its central concept" (van den BERGH, 2001, p. 15). In his comparisons, which includes a table of some 20 different items, the ones he emphasizes are the following: scale vs allocation; distribution and equity vs growth; the complex link between poverty and environment; environmental sustainability vs efficiency; and North-South welfare differences. From an extensive examination of the literature, though not comprehensive or exhaustive, below are the list of items

that appear to be most significant, taking into account a range of authors.

The major differences to be considered in this article between Environmental and Resource Economics and Ecological Economics, and its three variants are the following: (1) Open and closed Systems; (2) Methodological pluralism; (3) Multicriteria analysis; (4) Weak and Strong Sustainability; (5) Social metabolism; (6) Capital Accumulation; and (7) Thermodynamics and Entropy.

3 DIFFERENCES OF APPROACHES REGARDING MAIN ISSUES

For each of the main issues, the relevant differences between EE and ERE will be presented, and on occasion, if deemed important, differences between the 3 specific perspectives within EE, conservative, critical and radical, will also be included. One of the main tools for presenting the distinction between ERE and EE, is the contrast of the open and closed systems, as seen below.

(1) OPEN AND CLOSED SYSTEMS/ MULTIDISCIPLINARITY VS INTERDISCIPLINARITY

One of the major differences between these two approaches is that Environmental and Resource Economics treats the economy as a closed system, while Ecological Economics considers the economy within the Earth's biosphere, thus as an open system, incorporating the environment and recognizing the role of physical inputs and outputs. This contrast is evident below when comparing Figure 1A: The Economy as a Closed System with Figure 1B: The Economy as an Open System. The common circular flow diagram in most macroeconomics textbooks corresponds to the closed system view and is thus more associated with environmental and resource economics. It is composed of the standard four elements: families, firms and the two traditional neoclassical markets: one for factors of production and the other for goods and services, as seen in Figure 1A below. In contrast, Figure 1B, presents the economy within the biosphere, incorporating environmental elements and aspects beyond just strict economic categories.

One key difference introduced by ecological economics was the need to recognize that the economy does not operate independently but is within a biosphere. Therefore, by paying attention to energy and material flows, which are fundamental, especially from an ecological perspective, it clearly

Figure 1A: The Economy as a Closed System (associated with ERE)

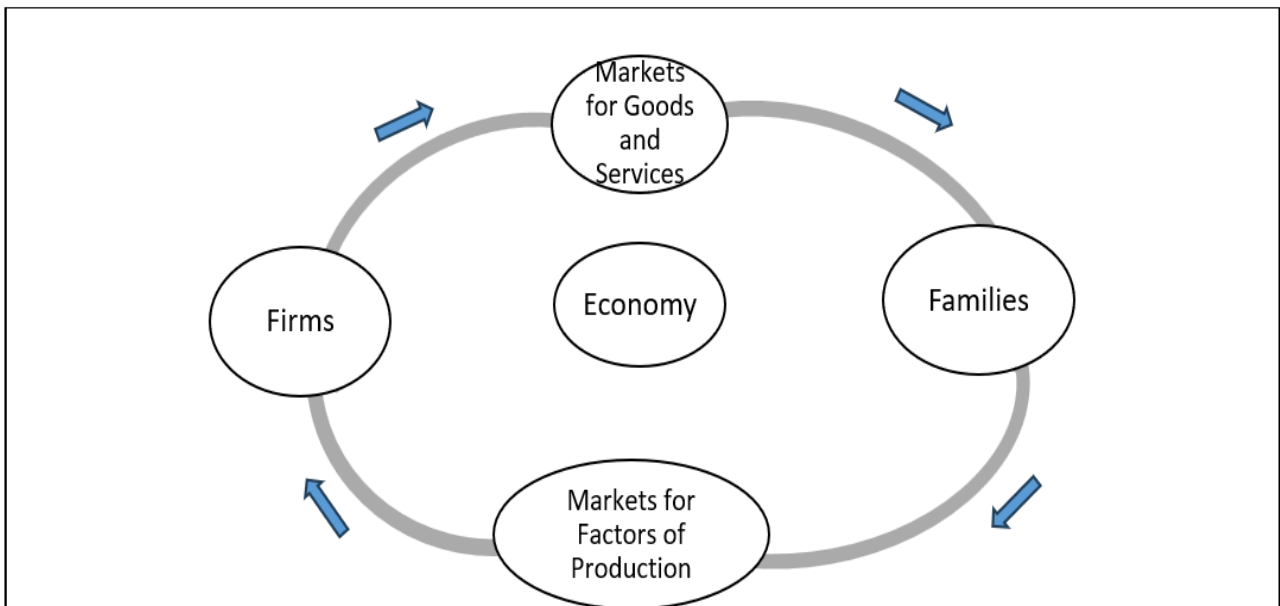
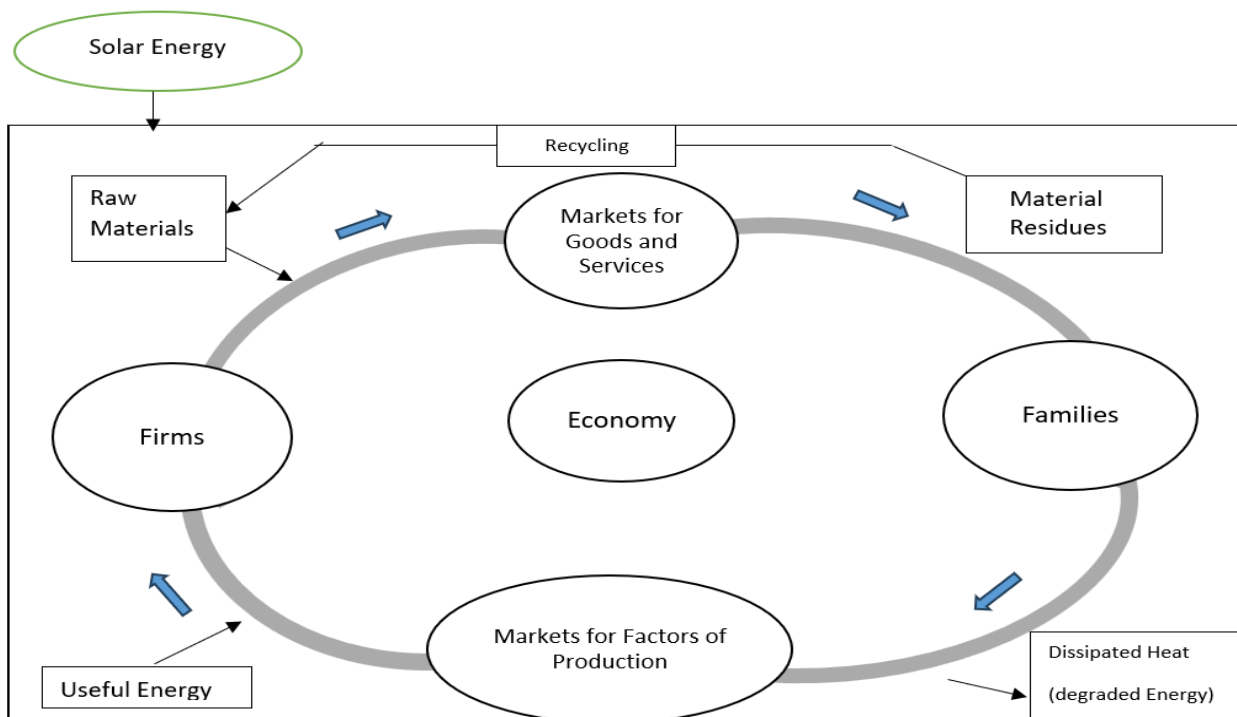


Figure 1B: The Economy as an Open System (associated with EE)



Source: Martínez-Alier and Jusmet (2006)⁶

distinguishes between useful energy and degraded energy, as in the case of

6. These two Figures were translated and modified slightly from Figures 1.1 and 1.2 in Martínez Alier and Jusmet (2006).

dissipated heat, which results from having used the energy for the generation of work⁷. Similarly, when considering material balances, ecological economics considers raw materials as inputs on the one hand, and the generation of waste and material residues on the other, and therefore the role of recycling is crucial. Conceptually, the open system clearly recognizes the economy's dependence on the environment in which it operates, recognizing both limits in terms of energy and materials and the generation of waste streams, often ignored by mainstream economics.

At an initial glance many will assume that the ERE approach is dominated by the neoclassical perspective and that ecological economics will be associated with heterodox economics, be it keynesian, evolutionary or marxist. Upon closer inspection, however, there is a significant presence and influence of the neoclassical perspective within ecological economics, though much more so in the Global North⁸. On the one hand the more conservative ecological economists may identify with the neoclassical framework but are critical of the orthodox neoclassical vision and thus will clearly identify with the open system in contrast to the closed system representation of the economy. Although some ERE economists today may accept the diagram of the open system but will not tend to go beyond that and in fact, many academic programs of environmental economics make a point to completely ignore and not even mention the existence of ecological economics.

B. MULTIDISCIPLINARITY VS INTERDISCIPLINARITY

The use of terms multidisciplinary, interdisciplinarity and transdisciplinarity is quite varied and even within EE there is not a consensus. The perspective which makes the most sense from discussions with several colleagues is the following. ERE is a clear example of simply multidisciplinary, in the sense that they will recognize multiple disciplines and the need for discourse but not make a serious effort to engage with other disciplines in order to more fully understand phenomena related to both economics and the environment. Ecological economics is interdisciplinary, taking the next step, be it an economist working with issues between economics and environmental science, biology, ecology, or thermodynamics, chemistry and

7. This distinction is of major importance in terms of thermodynamics as useful energy can produce work but once that takes place, although the total energy remains the same, the result is degraded energy, often the result of an irreversible process, and leading to increases in entropy as a result of the Second Law of Thermodynamics. This will be further discussed below.

8. The dominant presence of neoclassical economists, though non-orthodox are what corresponds to the conservative perspective presented above.

biophysical modeling. In other words, the effort extends beyond what is possible from mere multidisciplinary to the greater challenge of working with different fields, necessary for understanding and analyzing a specific phenomenon, or problem or issue, such as climate change. The third, and in my view, the most advanced example is that of transdisciplinarity, which implies going beyond what each discipline entails by itself and pursuing laws or explanations that cannot simply be categorized as economic, or as ecological but transcending separate disciplines, moving to a true synergy of two or more disciplines. This is the most challenging and is not necessarily so easily attained. The pursuit by NGR of the fourth law of thermodynamics was a transdisciplinary experiment, even though it did not produce scientifically rigorous results, in spite of the virtuous and courageous attempt by NGR⁹. This is discussed in more detail in the topic on thermodynamics and entropy below.

(2) METHODOLOGICAL PLURALISM

ERE is associated with not just the neoclassical perspective but the more orthodox neoclassical perspective which tends to rule out any alternative theoretical views or methodologies. Thus, they tend to see methodological individualism as the only foundation for economics, including environmental economics. Therefore, those with a slightly different take, say Post-Keynesians, Sraffians, or evolutionary economists, have needed to push for methodological pluralism within ecological economics. This has been necessary to avoid the absolute dogmatic methodological dominance of neoclassical orthodoxy. Thus, EE has clearly been the advocate of methodological pluralism in contrast to ERE.

It seems that the emphasis on methodological pluralism derives from the early years when the first ecological economists tended to be working with a neoclassical framework and using neoclassical tools. Evidently, they saw flaws in the application of certain tools or recognized the need to engage with other disciplines, such as the case of NGR working at the interface between economics and thermodynamics. In any case, it made sense to promote pluralism in the field and not be strictly limited to orthodox neoclassical economics.

As ecological economics grew, the problem with orthodox neoclassical dogma was felt even by those working with a neoclassical framework. With the arrival

9. There are many articles addressing this discussion and an example of a relevant survey of the supporters and critics of NGR's attempt to bridge thermodynamics and economics is an expected forthcoming article by Sacher and Cooney.

of people from different paradigms within economics, authors such as Martinez Alier (Keynesian/Sraffian perspective) and Spash (social ecological economics), it became fundamental for ecological economics to pursue methodological pluralism. It is arguable that this was a good idea for the period when EE was beginning, however, at the present point in time, there seems to be a disconnect between maintaining methodological pluralism and the need to break from the neoclassical perspective within EE. This constitutes an historical irony, given the fact that the original EE economists, such as Georgescu-Roegen, Daly, Costanza and others tended to work with a neoclassical framework. However, it may simply reflect the problems of the dominance of the neoclassical approach in academia, especially in the Global North. Unfortunately, this has meant a major limitation for so long of preventing economics, and ecological economics, from really addressing fundamental issues, such as understanding the relationship between capitalist accumulation and the environment.

(3) MULTICRITERIA ANALYSIS; VALUATION OF NATURE

The dominant view among ERE economists is that any relevant category, be it social, biological, physical, health-related, cultural, or otherwise, can simply be presented in monetary terms, especially through the use of different tools, but especially the contingency valuation approach. Thereby denying the need to consider fields or disciplines where criteria for ecological or physical categories, such as the total flow of energy or water or air concentration, or measures for biodiversity, or other qualitative categories, need to be included as criteria upon which one or a group of interdisciplinary scientists come together to seek solutions. In this regard, EE stands out as arguing clearly for multicriteria for doing analysis in the area of economics and the environment. Could you imagine a biologist telling economists and others that they need to convert all of their measures of financial flows, profits etc. into biological categories? This seems so absurd that the arrogance of the former should stand out to ERE economists but no, they think it is legitimate for issues involving multiple disciplines. This is a clear example of the limitations of a multidisciplinary approach compared to an interdisciplinarity one; but more striking, is the implicit arrogance and blindness of orthodox economists, when it comes to working collectively with other scientists from different disciplines;

Multicriteria Analysis is a concept employed by EE which according to Fuente (2008) is presented as a methodological proposal in contrast to or challenging the

focus of cost-benefit analysis of ERE. The latter is based on a single basis for criteria, namely expressions strictly in monetary terms. This is associated with the discussions of language or the concept of the valuation of nature and the associated category of “natural capital”, which is arguably absurd and incorrect. What is attempted by such an approach of using a single criterion? It attempts to defend the argument that monetary categories are sufficient to make decisions about the positives and negatives of a given project or approach, instead of recognizing the importance of different categories which are not commensurable and cannot be converted into monetary categories. Examples abound, such as biodiversity, the value of lives, of a pristine forest. Many biophysical categories, ecological or cultural categories simply do not have monetary equivalents. This is one of the biggest differences and practically constitutes a major obstacle, which ERE constitutes.

(4) WEAK AND STRONG SUSTAINABILITY

The discussions around sustainable development, as mentioned above, began with an association with the Brundtland Conference in 1987, and for some, this is strongly associated with the takeoff point of EE. Although the conference is more linked to the conservative version of sustainability and also the conservative perspective of EE, the following arguments presented by van den Bergh are quite relevant as a starting point. “There are various definitions of sustainability and especially of sustainable development... Notably, the opposition between strong and weak sustainability has received much attention in the last few years. Weak sustainability has been defined on the basis of the concepts “economic capital” and “natural capital”. Economic capital comprises machines, land, labour and knowledge. Natural capital covers resources, environment and nature. Under weak sustainability one strives for maintaining “total capital”, defined as the “sum” of both types of capital. This allows the substitution of natural capital by economic capital, as has been analysed in economic growth theory (SOLOW, 1974, 1986; HARTWICK, 1977). Strong sustainability, by contrast, requires that every type of capital is maintained separately. ERE starts from weak sustainability, which emphasises a large degree of substitution of inputs in production and the economy as a whole. This has been criticised by EE (see Ecological Economics vol. 22, 1997). Within EE, usually some type of strong sustainability is emphasised, which is operationalised through goals such as protection of critical ecosystems, striving for at least a minimum area of nature, or maintenance of biodiversity” (van den BERGH, 2001, p. 17).

Given the more conservative view of van den Bergh, it is necessary to also consider the perspective of the critical and radical versions of EE in presenting their version of strong sustainability. According to Barkin et. al.: “In the definition of sustainability, there is no possibility of replacing many non-renewable natural resources or the loss of biodiversity; as a consequence, this requires non-market measures in order to conserve renewable resources and restrict or limit the use of non-renewable resources with the aim of approaching a strong sustainability” (BFT, 2012, p. 5).

Others from the radical perspective, such as Burkett (2006), O’Connor, and Foster, will argue that the neoclassical/capitalist discourse and institutions constitute an epistemological obstacle in order to address the issue of sustainability. At this point, it could be argued that there is a problem with methodological pluralism, insofar as it prevents rejecting the pro-market, pro capitalism discourse, inherent in the neoclassical approach. Such a view supporting strong sustainability, markedly in contrast to the weak sustainability associated with an overaccommodation to capitalist accumulation.

(5) SOCIAL METABOLISM

The topic of social metabolism is strongly associated with EE and given its association with interdisciplinarity, it is unlikely that ERE has paid any serious attention to it. Social metabolism or socioeconomic metabolism is the set of flows of materials and energy that occur between nature and society, between different societies, and within societies. These human-controlled material and energy flows are a basic feature of all societies, but their magnitude and diversity largely depend on specific cultures, or sociometabolic regimes (TOLEDO, 2014) Social or socioeconomic metabolism is also described as “the self-reproduction and evolution of the biophysical structures of human society. It comprises those biophysical transformation processes, distribution processes, and flows, which are controlled by humans for their purposes.” (PAULIUK, STEFAN and HERTWICH, EDGAR G., 2015).

Social metabolic processes begin with the human appropriation of materials and energy from nature. These can be transformed and circulated to be consumed and excreted finally back to nature itself. Each of these processes has a different environmental impact depending on how it is performed, the amount of materials and energy involved in the process, the area where it occurs, the time available or nature’s regenerative capacity (TOLEDO, 2014). Social metabolism represents an extension of the metabolism concept from biological organisms like human bodies

to the biophysical basis of society. In capitalist societies, humans build and operate mines and farms, oil refineries and power stations, factories and infrastructure to supply the energy and material flows needed for the physical reproduction of a specific culture. In-use stocks, which comprise buildings, vehicles, appliances, infrastructure, etc., are built up and maintained by the different industrial processes that are part of social metabolism. John Bellamy Foster has analyzed Marx's argument regarding the metabolic rift associated with the transition from rural to urban societies and has extended this concept further by analyzing the deleterious effect of capitalism on ecosystems in the present-day (FOSTER et. al., 2010).

(6) CAPITAL ACCUMULATION

The category of capitalist accumulation for those of the radical perspective within EE, is the fundamental economic process of capitalism, and this incessant drive is a major factor in producing the environmental problems and crises, going as far back as the early 19th century in England, but even much more so now. The majority of those associated with EE, especially the conservative perspective will tend to never use the term. Within ERE, such an analysis or term is avoided, even though they would not deny the importance of growth for capitalist firms but will tend to emphasize GNP and not even acknowledge the importance of capital accumulation.

Unfortunately, within economics and more sadly within ecological economics, such a term as capitalist accumulation is associated with marxism and is therefore avoided. This is quite ironic given the incredible importance and presence of discussions of degrowth within economics, but especially ecological economics. The reality is, if one pursues degrowth, one is pursuing the end of capitalism, since accumulation is fundamental and requires growth and capitalists are not just going to be convinced of the arguments of degrowth and turn over their wealth. Given this fundamental issue ecological economists need to recognize accumulation as not only the dominant economic driver in capitalist societies, but its relationship with the environment, especially as this may be required to understand the nature of current environmental problems and what is required for future solutions.

Spash, is a major advocate of social ecological economics and the idea of a transformation to an alternative future. He sees this as now forming core ideas in an interdisciplinary approach combining insights from a range of disciplines including heterodox economics, political ecology, sociology, political science, social psychology, applied philosophy, environmental ethics and a range of natural

sciences. He is also an advocate of a post capitalist society and also for activism in order to achieve a better world for society and nature. Such a far-reaching perspective involving a break from the current capitalist system places him as a radical in my opinion, even though he does not explicitly advocate a marxist *Weltanschauung* but does refer to eco-marxism.

(7) THERMODYNAMICS AND ENTROPY;

Another topic often referred to in ecological economics is the role of thermodynamics and entropy, associated with the pioneering work of Georgescu-Roegen (1971), which produced significant debate within environmental economics, ecological economics and physics around issues of scarcity, waste processing and recycling, to overall discussions around the existence of limitations on the economy due to the environment.

In discussions related to NGR it is not simply how economics and thermodynamics are interrelated but specifically issues around material scarcity and potential as well as problems regarding recycling. One of the major debates between NGR and his defenders with some of the ERE has been whether technological advances with regards to solar energy capacity and whether 100% recycling is possible. A major aspect which is not discussed enough, except by the more radical ecological economists, as mentioned above, is insatiable capitalist accumulation, and how this has exacerbated ecological and environmental crises in recent decades¹⁰. This cannot be ignored, nor the arguments stressed by Barry Commoner and others relating to the nature of the inputs and outputs of our production processes, and in particular, the subsequent generation and treatment of waste. This clearly is connected up with the efforts and policies for recycling, and how the current state of affairs make the concept of "100% recycling" seem like that of science fiction.

NGR has often been referred to as the father or perhaps now, the grandfather of ecological economics¹¹, given his direct influence and also being the professor of Herman Daly at Vanderbilt who was then the professor and colleague of Constanza, who played such a fundamental role in the early years of the journal *Ecological Economics*. NGR was seen as a trailblazer of the field and challenging neoclassical

10. This discussion within ecological economics, though not referring to accumulation, clearly began with the pioneering work of Daly on a steady-state economy (DALY, 1977), but which has seen increased attention and discussion especially in the context of debates on degrowth.

11. NGR actually preferred the term bioeconomics, not ecological economics.

orthodoxy to address the serious problems of the impact of the economy on the environment. Moreover, he sought to discern the limits and the role of scarcity from biology and physics and pursued an interdisciplinary, if not transdisciplinary, project examining the influence of thermodynamics on economics. He came to develop the fourth law of thermodynamics and the strong conclusion regarding the impossibility of 100% recycling.

There was major criticism of this development and his concept of entropy-matter, predominantly by the "Solar Prometheans", mostly from a neoclassical economic perspective, but among the critics, were ecologists, biologists and physicists and the conclusion was that his proposed 4th law of thermodynamics lacked rigor from within physics. Thus, in spite of having a noble pursuit of seeking to understand the energy and material limits on production in a capitalist society, with its incessant demand for growth, he overstepped the boundary of scientific rigor. Unfortunately, many in the field of EE tended to just accept what he did at face value, having little familiarity with thermodynamics and physics, which is the norm within the economics profession. ERE, with its tendency to accept neoclassical orthodoxy, aligned with those of the Solar Prometheans and did not consider NGR relevant.

The reality is a bit more complex, and in a forthcoming article on the topic of NGR's contribution and the role of thermodynamics with respect to economics, my colleague William Sacher and I have researched this issue extensively and conclude that he is to be recommended for his trailblazing effort and influence on the early founders of ecological economics. However, there is a need to accept much of the criticism from the field of physics, and to continue the research necessary to understand to what extent there are or not limits in terms of energy and matter for economic processes. One may rule out NGR's attempt to develop the 4th law, however, there are serious and legitimate concerns regarding the continued exploitation of fossil fuels, and minerals and how this can impact ecological crises in the present and into the future for humanity.

In this third section, the differences of approaches was considered for seven main topics: (1) Open and closed Systems; (2) Methodological pluralism; (3) Multicriteria analysis; (4) Weak and Strong Sustainability; (5) Social metabolism; (6) Capital Accumulation; and (7) Thermodynamics and Entropy. This was carried out by contrasting the ERE perspective with EE, predominantly with regards to theory and method, and on occasion, contrasting the three distinct perspectives within

Ecological Economics, namely the conservative, critical and radical versions.

4 CONCLUSIONS

The main aim of this article was to present a comparison of the two major approaches related to the study of economics and the environment, namely Environmental and Resource Economics and Ecological Economics. One of the key differences was made clear from the contrast of the open and closed economy in Figure 1A and 1B above. Ecological Economics considers the economy within the Earth's biosphere, thus as an open system, incorporating the environment and recognizing the role of physical inputs and outputs, in contrast to the limited closed system associated with ERE. Throughout the article, the advantages of incorporating environmental elements and aspects beyond just strict economic categories became evident. Another major contrast is that between a multi-disciplinary approach associated with ERE versus an interdisciplinary approach, if not transdisciplinary, associated with EE. Evidently, the latter brings economics into dialog with many other disciplines, including biology, ecology, environmental sciences, geography, geology, and sociology. Although both clearly are grounded in economics, ecological economics has a much broader foundation. EE also incorporates the richer heterodox tradition in contrast to the strict neoclassical orthodoxy which predominates ERE.

The major differences considered between the conservative, critical and radical perspectives within EE are in summary, related to theory and method. The conservative perspective continues to work with a neoclassical framework though rejecting certain aspects and emphasizing the need to consider key aspects connected to the environment, such as biophysics, thermodynamics, etc. The critical perspective is more associated with Keynesian, post-keynesian, institutionalist and evolutionary economics, among other heterodox frameworks and thus makes a clear break from neoclassical orthodoxy. However, in spite of this break and a recognition of the problems of a capitalist economic rational dominating decision-making and theoretical arguments, the radical perspective goes further in arguing for the need to recognize the problems of capitalist accumulation, especially when considering its impacts on the environment, but also recognizing the crucial role of social movements and class struggle. Evidently, this division within ecological economics will have gray areas or researchers which overlap the distinctions just alluded to. Nevertheless, it can be argued that the radical view is necessary to identify the root causes of environmental crises and disasters, in order to promote serious and

successful environmental policy for the medium and long run, though the short run seems to require radical solutions at times, as well.

Evidently the relevance of comparing environment and resource economics with ecological economics is not just identifying differences in theory and method but rather there are the real and concrete issues which affect the everyday lives of people all over the globe. There is a seemingly endless list of issues: from climate change, deforestation, acidification of the oceans, drastic reduction of biodiversity, loss of species at a massive scale, the problems of pesticide-linked GMOs (e.g., bees, the loss of our traditional seed base, human health issues), thanks to Bayer/Monsanto, the unprecedented level of contamination and pollution of our air, water and soil, forest fires, floods, ocean temperature rise, melting of the polar ice caps, shifts in agriculture and natural biomes, contamination of plastics on land and sea, the decline of coral reefs, and the list goes on. This article concentrated on contrasts of theory and method but subsequent research along the same lines is necessary for presenting a comparison and contrast of the different perspectives with regards to these specific issues in practice. Furthermore, such research needs to emphasize the field of ecological justice given the intertwined aspects of social and economic inequality connected to environmental and ecological inequality.

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