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ECOLOGICAL ECONOMICS

Abstract

Ecological economics was constituted in the late 1980 as a transdisplinary field of study attracting systems ecologists and dissident economists. Inspiration was drawn from N. Georgescu-Roegen's *The entropy law and the economic process* (1971) together with work from ecologist H. T. Odum and economist K. Boulding. The complexity of living structures is achieved by "capturing" energy through photosynthesis and by dissipating energy to outside systems. The industrial economy, however, does not work only by using current photosynthesis. It burns irreplaceable stocks of fossil fuels, and it produces irreversible damage to the natural environment. The scale of the economy is too large, therefore the natural cycles cannot sustainably produce the resources or absorb or assimilate the waste such as, for instance, heavy metals or excessive carbon dioxide. Ecological economics encompasses money-valuation of positive environmental services and of negative externalities, and also physical appraisals of the environmental impacts of the human economy measured through new indicators. It also gives importance to social indicators. The study of the relations between property rights and management of natural resources is another important focus. Ecological economics favors multi-criteria assessments over cost-benefit analysis, emphasizing incommensurability of values. It has also developed an ecological macroeconomics without growth.

Key Words

Human ecology. Social metabolism. Entropy. Steady-state economy. Strong sustainability. Environmental economics. Economic valuation. Environmental services. Property rights.

1. Introduction

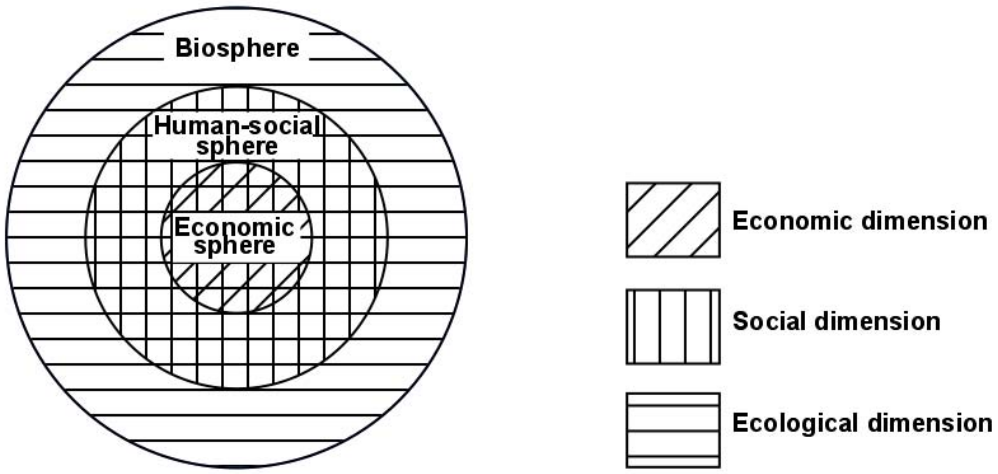
Ecological economics is a transdisciplinary field of study which sees the economy as a subsystem of a larger finite global ecosystem. Ecological economists question the sustainability of the economy because of its environmental impacts and its material and energy requirements, and also because of the growth of population. Attempts at assigning money values to environmental services and losses thereby correcting macroeconomic accounting, are part of ecological economics, but its main thrust is rather in introducing physical indicators and indices of sustainability. Ecological economists also work on the relations between property rights and resource management, they model the interactions between the economy and the environment, they study ecological distribution conflicts, they use management tools such as integrated environmental assessment and multi-criteria decision aids, and they propose new instruments of environmental policy.

From the beginning of ecological economics (Daly, 1984) there was a debate between three approaches. First, to go beyond the mere description of the human economy in ecological terms (flows of energy and materials, evolution of technologies in analogy to biological evolution) and search for a physical common value (such as energy value). Second, to follow the strategy of hanging a price tag on everything, using fictitious market prices when actual market prices are lacking. While the first and second approaches are reductionist, the third approach is not reductionist but transdisciplinary.

2. The economy embedded in society and nature

René Passet in 1979 in *L'économique et le vivant* drew an image of the relations between nature, human society and the human economy (Fig 1) that has become a symbol for ecological economics.

Fig. 1. The economy embedded in the institutions of human society and in the biosphere



The drawing shows the obvious reality that there was nature before human society, and human society preceded the generalized market system by many generations. This vision has implications for economics. The teaching of the theory of externalities (i.e. the impacts of the economy on the environment which are not measured by market prices) should not wait for the time when students have grasped already the analysis of general market equilibrium. On the contrary, the study of the market (the chrematistics) should come after the study of ecology and social institutions. The “externalities” come before the “internalities”. The market economy could not exist without social institutions, and without the unpaid products and services of ecosystems.

Ecological economists see the economy as an open system. In thermodynamics, systems are classified as "open" to the entry and exit of energy and materials, "closed" to the entry and exit of materials though open to the entry and exit of energy, such as the Earth, and "isolated" systems (without entry or exit of energy and materials). The availability of free energy and the cycling of materials allow life forms to become ever more organized and complex; the same applies to the economy. Dissipated energy and waste are produced in the process. If the scale of the economy is too large and its speed is too rapid, then the natural cycles cannot sustainably produce the resources or absorb or assimilate the waste such as, for instance, heavy metals or carbon dioxide.

In ecological economics the economy is seen as embedded in the ecosystem (or, more accurately, in the historically changing social perception of the ecosystem). The economy is also embedded in a structure of property rights on environmental resources and services, in a social distribution of power and income, in social structures of gender, social class or caste. Instead, in mainstream economics the economy is seen as a self-sufficient system where prices for consumer goods and services, and prices for the services of production factors, are formed.

Ecological economists (Norgaard, 1990) disputed the view expressed in the 1960s by Barnett, Krutilla and other mainstream resource economists, that since raw materials were cheap, they must be abundant. Markets are myopic, they discount the future, they cannot see future uncertain scarcities of sources or sinks. Ecological economists understand and even sympathize with attempts at "internalizing" externalities into the price system, they readily concur with proposals to correct prices by taxes (such as "natural capital depletion taxes" or taxes on pollution) but they deny that there exists a set of "ecologically correct prices".

3. History and Foundations

In the late 19th c. and early 20th c. the biologist and urban planner Patrick Geddes, the chemist Frederick Soddy, the engineer and social reformer Josef Popper-Lynkeus had unsuccessfully tried to promote a biophysical view of the economy, as a subsystem embedded in a larger system subject to the

laws of thermodynamics (Martinez-Alier and Schlüpmann, 1987). By 1850 or 1860 the carbon cycle and the cycles of plant nutrients had been discovered, while the first and second laws of thermodynamics (conservation and transformation of energy, but also dissipation of energy and increase in entropy) had been established.

The contrived conflict between the "optimistic" theory of evolution which explained the diversity of life, and the "pessimistic" second law of thermodynamics, was a staple of the cultural diet of the early 1900s. Praising the energy accounts of agriculture published in 1880 by the "narodnik" revolutionary and physician S. A. Podolinsky, the ecologist Vernadsky wrote in 1924 (Vernadsky, 1924, p 334-5) that Podolinsky had analyzed the energetics of life (life systems being open to the entry of energy), and had applied these ideas to the analysis of the economy. Podolinsky wrote that, for an economy to be sustainable, the energy productivity of human work (i.e. how much energy is made available by one day of human work) must be higher (or equal, if everybody is working) than the efficiency of the transformation of the energy intake into human work. The energy productivity of a coal miner (wrote Podolinsky) was much larger than that of an agriculturalist could obtain but this energy surplus from fossil fuels was transitory (Podolinsky, 1880, 1883).

Therefore, the main ingredients for an ecological view of the economy were present much before the birth of a self-conscious ecological economics in the 1980s, which was delayed by the strict boundaries between the natural and the social sciences. The biologist and systems ecologist Alfred Lotka, born in 1880, had introduced in the 1910s and early 1920s the fundamental distinction between the endosomatic use and the exosomatic use of energy by humans. While we have genetic instructions on the amount of food energy to be consumed (about 7 to 10 MJ per day for an adult), our exosomatic use of energy depends on culture and income, and reaches 1 GJ or more per day for rich people.

Much later, four well-known economists, who did not yet form a school, are seen in retrospect as ecological economists: Nicholas Georgescu-Roegen (1906-94), the author of *The Entropy Law and the Economic Process* (1971) (where Lotka was often quoted), Kenneth Boulding (1910-93), who worked mainly on general systems analysis, K. W. Kapp (1910-76) and S. von Ciriacy-Wantrup (1906-80), who were both institutionalist economists. The systems ecologist H. T. Odum (1924-2002) studied the use of energy in the economy and some of his former students were among the first ecological economists in the 1980s. Other sources of ecological economics are in Environmental and Resource Economics (microeconomics applied to environmental pollution and the depletion of natural resources), in Human Ecology, Ecological Anthropology, Agroecology and Urban Ecology, and in the study of "industrial metabolism" as developed by Robert Ayres (born in 1932), now known as Industrial Ecology.

The first books or special issues of journals with the title “Ecological Economics” appeared in 1987. After meetings in Stockholm and Barcelona with a large group of ecologists and economists, Robert Costanza and Herman Daly set up the International Society for Ecological Economics (ISEE) and convened the first world conference in Washington DC in 1990. The book that came out of this first conference (Costanza ed., 1991) ambitiously defined the field as "the science and management of sustainability". The successful academic journal *Ecological Economics* started in 1989, edited first by Robert Costanza, and later by Cutler Cleveland (who also edits the Encyclopedia of the Earth) and Richard Howarth.

Some environmental economists of neoclassical persuasion were also present in those early efforts. David Pearce became one of the main editors of the new journal, *Ecological Economics*, but he left the journal after 1994 because of internal disputes on what is now called “weak sustainability vs. strong sustainability”. Pearce had influenced the World Bank to do macroeconomic accounts in which “human-made capital” could in theory substitute for so-called “natural capital”. This was “weak sustainability”, i.e. sustainability in the weak sense of the term. Herman Daly, Peter Victor and other ecological economists objected to “weak sustainability”. One could not sustainably substitute the increased horsepower of the fishing fleet for a declining availability of fish. Moreover, measurement of stocks of capital depended on the rate of profit (as discussed in the controversies on capital theory of the 1970s) (Victor, 1991).

However, the ISEE is a scientific society encouraging internal controversy and also a product of the environmental movement of the 1960s and 1970s in its different varieties. Internal pluralism and

perhaps some confusion of ideas were present in the volume produced after a second ISEE conference in Stockholm in 1992, *Investing in Natural Capital: the ecological economics approach to sustainability*. While some ecological economists feel even today that the metaphor of "natural capital" is useful, others strongly reject it because it suggest that we can use "units of capital" as a common measuring rod that would make commensurable the losses of biodiversity and the increases in manufactured capital stocks. The notion of "natural capital" supports policies such as "habitat trading" (one habitat is destroyed and another one, far away, is effectively protected) or the Rio Tinto mining company's doctrine of "net positive impact" (a new location is destroyed while another is preserved and enhanced, going round the world until no natural spaces would be left).

While H. T. Odum (and his disciples working on human ecological energetics: A. M. Jansson, Robert Costanza, Charles Hall, Cutler Cleveland), David Pimentel with Mario Giampietro (agricultural energetics) and C. S. Holling ("resilience") were the ecologist grandfathers, mothers and fathers of ecological economics, K. Boulding and N. Georgescu-Roegen were the economist grandfathers. (K. W. Kapp had died early, missing the birth of ecological economics). Herman Daly's influence was also decisive. Daly (born in 1938) published his first article in what we now call ecological economics in 1968 in *The Journal of Political Ecology*. In the early 1990s (Daly and Cobb, 1989) he promoted an index of sustainable economic welfare (ISEW) expressed in money terms that showed results very different from GDP (because of the different assumptions in the calculations). It seemed at the time that ISEW was a good way to attack GDP accounting but an index in money terms was not congruent with the critique against "weak sustainability". Daly maintained his stature in the field and recently increased it as his early defense of a Steady State economy (Daly 1973) is now seen as having announced the new ecological macroeconomics without growth (Victor, 2008; Jackson, 2009).

Daly was explicitly inspired in his work by Boulding and Georgescu Roegen. Boulding had published a famous article on *The Economics of the Coming Spaceship Earth* (a spaceship where materials would have to be recycled) (Boulding, 1966). He became a card-carrying member of the ISEE and an author in the collective book edited by Costanza (1991). Georgescu-Roegen refused to be drawn into the ISEE; he preferred to call the field "Bioeconomics" (Mayumi, 2001; Bonaiuti, 2011) and announced the publication of a book with this title that never appeared. He disliked Costanza's article in *Science* in 1980 (Costanza, 1980) proposing an energy theory of value, he disliked also H.T. Odum's "emergy" (embodied energy) accounts to which he answered with an irritated reply: "matter matters too" (Georgescu-Roegen, 1977) against what he called the "energetic dogma". On the other hand, Boulding, more concerned with scarcity of materials than with energy dissipation, wrote a less than enthusiastic review of Georgescu-Roegen's magnum opus. In due course the edition of the collected works and correspondence of such major intellectual figures and pioneers of ecological economics will clarify the real substance, if any, in such disagreements and quarrels.

Georgescu-Roegen's point on the importance of entropy for the economy is as follows. Life is "negentropic": Georgescu cited very often Schrödinger's *What is Life* (1944). The evolution of species, the complexity of living structures, was achieved by "capturing" energy through photosynthesis, and by dissipating energy to outside systems. The industrial economy, however, after the thermo-industrial revolution (Grinevald, 1976) did not work only by using current photosynthesis or hydraulic energy. It was burning stocks of fossil fuels. Even a non-growing industrial economy would not be sustainable because energy cannot be used twice (except in minor cases of "co-generation"). In any day in 2013 we take 90 million of barrels of oil from the "subterranean forest" (Sieferle, 2001), tomorrow we do the same again, a little more or a little less, whether from the bottom of the sea or from fields in Irak or Saudi Arabia, the rainforest of Ecuador or the Orinoco Delta in Venezuela. Perhaps the EROI is declining (the energy return on the energy input) or perhaps not yet. Georgescu was also very aware of the approaching Hubbert's "peak oil".

Although we could claim that Darwin won against Sadi Carnot (Prigogine and Stengers, 1984), in the industrial economy the sources of low-entropy become scarcer. Moreover, materials cannot (in practice) be recycled to the full extent (an observation that Georgescu tried to glorify into a 4th Law of Thermodynamics, without success, Mayumi, 2001). Georgescu saw the economy as a system open not only to the entry of energy and materials but also to the unavoidable exit of inconvenient and unrecyclable "garbojunk" (a word formed by garbage + junk).

Georgescu's fundamental contribution to ecological economics was then that, because of the Second Law of Themodynamics or Entropy Law, even a non-growing industrial economy is not sustainable. Therefore, in the rich economies, a "steady state" (as proposed by Daly, drawing on Stuart Mill), would not be enough. A steady state economy aims for mildly fluctuating levels in population and consumption of energy and materials. Birth rates equal death rates, and (in economic terms) saving/investment equals depreciation. Georgescu said that in rich countries a degrowth in the inputs of fossil fuels and other materials was required. Hence Georgescu's agreement to the French title to a selection of his articles edited by Grinevald in 1979, *Demain la Décroissance.* In retrospect, this book became 25 years later one main inspiration for the European "degrowth" movement (Martinez-Alier et al., 2010). Nobody ever preached a 100% degrowth of the economy. Georgescu's lower limit would be that of an economy fuelled by the current inflow of solar power. There is therefore a confluence of ideas between Georgescu's degrowth, Daly's steady-state (Kerschner, 2010) and the new ecological macroeconomics without growth.

Apart from the United States and Europe, the Japanese "entropy school" of economic analysis (Tamanoi, Tsuchida, Murota, 1984) studied the environmental services provided by the water cycle, and also the ancient urban ecosystems of Japan. In India, there was much work since the 1970s by economists but also by ecologists (Madhav Gadgil) on the links between forest or water management and common property rights, nowadays one main focus of interest in ecological economics (Berkes and Folke eds., 1998; Agarwal, 2010). Other early ecological economists (whose major works were not in English) are, in France, Rene Passet (1979), and Ignacy Sachs who proposed in the early 1970s the notion of "eco-development"; Roefie Hueting (1980) in the Netherlands and Christian Leipert in Germany; Jose-Manuel Naredo in Spain (Naredo, 1987). (For general introductions to the field: Costanza et al. eds., 1997; Cleveland et al., 2001; Martinez-Alier and Røpke eds., 2008, Spash ed., 2009).

4. A new ecological macroeconomics without growth

Keynesian macroeconomics initial concern was the "short term". One prescription for times of economic crisis was increased "deficit spending" (increasing the public debt) to finance public expenditure thereby increasing employment, to compensate for the decline in private investment that caused the economic crisis. However, such public investment would by itself increase the productive capacity of the economy; therefore in the long run there was a need to increase again aggregate demand. Keynesianism became a doctrine of continuous economic growth through the Harrod-Domar models of the 1950s. In 2008-09, a new ecological macroeconomics without growth made a breakthrough in public opinion, due to two ecological economists of long standing, Peter Victor and Tim Jackson. A Keynesian-inspired macroeconomics without economic growth is a novelty that ecological economists are offering the world. Ecological economists had previously tried to engage with Keynesian and post-Keynesian economics (Daly and Farley, 2010, Holt et al, 2009) and there was also the tradition of a steady-state economics.

Peter Victor gives several reasons why a country like Canada should no longer have economic growth. Economic growth as measured by changes in GDP is inextricably related to increases in materials and energy despite gains in efficiency over time. The historical record shows a positive link between economic growth and increasing flows materials and of energy (measured as work done, Ayres and Warr, 2009). In fact, gains in efficiency sometimes contribute to increased material and energy throughput because of the operation of Jevons' Paradox, also known as the "rebound effect".

How could we manage without growth, at least in advanced economies? These economies are very wealthy as measured by consumptions standards but happiness or life satisfaction has not increased pari passu with income and consumption. The so-called Easterlin's Paradox states that life satisfaction does not grow above a certain level of income, perhaps 15 000 USD per capita/year.

Through simulation models Victor then shows that a non-growing economy in Canada could maintain life satisfaction, achieve nearly full employment, eliminate poverty, and significantly reduce greenhouse gas emissions. Simultaneously, the weight of the public debt relative to GDP would decrease. Perhaps more than the results, which depend as usual on the assumptions of the models, the striking novelty is in Victor's question itself, "is managing without growth possible?" (2008).

Meanwhile, Tim Jackson wrote a report for the British government in 2008 with the title: *Prosperity without growth?* (Jackson, 2009). He argued that consumer debt had increased far too much before the economic crisis of 2008 while the public debt would be increasing enormously after 2008 in many countries. Debts can be settled by inflation (money loses value), or by impoverishing the debtors (what some Greeks call "debtocracy", creditors' rule), or by economic growth. Here Jackson recalls again not only the well known critiques of GDP but also the research on Easterlin's Paradox.

Jackson asked repeatedly for "financial prudence", not only because of the risk of default but even more because debt repayment requires economic growth, and growth in rich countries is to be avoided for ecological and social reasons. The ecological reasons are clear. If world trends of 2007 would continue, then in order to keep carbon dioxide concentration below 450 ppm, the carbon intensity of the rich economies would have to decrease over one hundred times by 2050. This seems impossible. The greenhouse effect was emphasized by Jackson more than "peak oil" and other planetary boundaries such as biodiversity loss. It sufficed him to make the point.

The development of human potential should not and cannot be achieved by increased consumption of "positional goods". Therefore, stopping economic growth is sound from the ecological and economic viewpoints and also socially. Lack of growth requires a revaluation of the goods and services we can get from the commons without damaging the welfare of other people. Jackson gives then policy recommendations based on this ecological macroeconomics. If there is no economic growth, unemployment will increase, given the trend to increased labor productivity because of technical change and the drive for profits. While André Gorz shockingly said *adieu au prolétariat* already in 1980 (not in China or India but in Europe), Jackson is concerned with "the stigma of unemployment". Hence, support must be given to the so-called Cinderella sector (which, remembering William Morris, one could call the "News from Nowhere" sector). This sounds naïf but it is well thought out. One virtue of this sector is precisely low labour productivity and the capacity to give massive useful employment. Jackson's other policies are a basic universal citizen's income and work sharing, and also investments in renewable energy and in ecosystem restoration and enhancement. Since such investments are unlikely to give a high rate of return in money terms, the share of savings (or taxes) and the role of the public sector of the economy will have to grow. Does this means a retrenchment of capitalism? Don't get excited about words, is Jackson's motto. But the question remains whether a non-growing capitalist system is possible at all.

5. Financial debts compared to real wealth

The amount of real wealth that an economy can create is limited by the amount of low-entropy energy and materials that it can sustainably take from the external environment, and by the amount of effluents such as the greenhouse gases that the environment can sustainably absorb. Jackson's "financial prudence" is not a new doctrine in ecological economics, on the contrary. The Nobel Prize in Chemistry and expert on radioactivity Frederick Soddy wrote on energy and the economy from 1910 onwards. He compared "real wealth" which grows at the rhythms of nature and which, if turned into manufactured capital, is worn down, with "virtual wealth" in the form of debts which apparently could grow forever. Private property in a capitalist system guarantees (for a while) the increasing private debt while the public debt could apparently grow based on the guarantees provided by the State. But this was a flimsy building.

Soddy was quoted by Daly and other ecological economists since the 1980s, much before the financial crisis of 2008. Debt-fuelled growth was not viable. The real fuel of economic growth was coal, oil, gas. Yes, life is negentropic but even eucalyptus cannot grow for more than fifteen or twenty years at 8% per year. Then they stop growing. Soddy's book of 1926 was called *Debt, Wealth and Virtual Wealth*. He drew on John Ruskin. He meant that Debt was not real wealth, it was virtual wealth. Real wealth was the current inputs of solar energy. Although ecological economists have not developed a consensual monetary reform plan, they follow Soddy on the need for "financial prudence" recommending for instance a large increase in the cash reserve requirements of banks (Daly and Cobb, 1989).

Soddy approvingly quoted Aristotle's distinction between Oikonomia and Chrematistika, as Marx had done and Karl Polanyi (1957) was to do later. Ecological economists are fond of this distinction. Oikonomia meant the study of the material provisioning of the oikos (the extended family) while

chrematistics was the art of studying market prices to make money, for instance by becoming a monopolist (a word used by Aristotle). What Aristotle called Oikonomia would now be called human ecology and economic anthropology, while Chrematistics is what students of microeconomics learn.

6. Irreducibility of Needs

In economic theories of production and consumption, compensation and substitution reign supreme. Not so in ecological economics, where diverse standards of value are deployed "to take Nature into account" (O'Connor and Spash eds., 1999). In the ecological economics theory of consumption, some goods are more important and cannot be substituted by other goods (economists call this a "lexicographic" order of preferences). Thus, sacredness cannot be traded off. And no other good can substitute or compensate for the minimum amount of endosomatic energy or for water necessary for human life. To call either the endosomatic consumption or the exosomatic use of energy a "socially constructed need or want" would leave aside the ecological explanations and/or implications of such use of energy, while to call the daily endosomatic consumption a revealed preference would betray the conventional economist's metaphysical viewpoint.

There is another approach which, as pointed out by John Gowdy and Susan Mesner (1998), builds upon the "principle of irreducibility of needs" (proclaimed by Georgescu-Roegen in the 1968 edition of the Encyclopedia of the Social Sciences, article on "Utility"). According to Max-Neef (Max-Neef, 1992) all humans have the same needs, described as "subsistence", "affection", "protection", "understanding", "participation", "leisure", "creation", "identity", "freedom"... and there is no generalized principle of substitution among them. Such needs can be satisfied by a variety of "satisfactors". Instead of taking the economic production as given, we may ask (as in the Steady-State and *Décroissance* perspectives) why is there so much travel, why so much building of houses with new materials instead of restoration of old ones... Is there a trend to use "satisfactors" increasingly intensive in energy and materials in order to satisfy predominantly non-material needs?

7. Against commensuration

One of the foundations of ecological economics is incommensurability of values although ecological economists understand and have pushed sometimes for the economic valuation of ecosystem services, with the avowed intention of making them more visible to the general public and to policy makers who are assumed to think mainly in money terms. Nevertheless, the insistence on money valuation clearly makes less visible the biological and ecological importance of Nature, and also livelihood and cultural values. The beauty and sacredness of a mountain such as the Niyamgiri Hill in Odisha might seem negligible when compared to the very large money value of its bauxite deposits. The mountain is better defended outside money valuation (Temper and Martinez-Alier, 2013). The debates on when is money valuation appropriate continue in ecological economics (Kumar, 2010). A consensus is perhaps being reached that money valuation is appropriate when trying to make companies accountable in civil litigation for their past environmental liabilities (as in the British Petroleum case in the Gulf of Mexico, Chevron-Texaco in Ecuador or Shell in the Niger Delta) but it is not appropriate for taking decisions for the future (whether on climate change or biodiversity policies or on building an open cast mine or a dam), when money valuation becomes only one of several relevant valuation languages.

In evaluating investment projects, ecological economics favors participatory multi-criteria evaluation (Munda, 2008) and deliberative methods (Zografos and Howarth, 2008) over cost-benefit analysis (CBA). This is not only because of “technical” problems with CBA (which discount rate to use, which methods of money valuation to apply to non-market goods and services or to negative “externalities”) but mainly because of a political question: Who has the power or the right to simplify complexity by imposing a single valuation language? Most ecological economists (but not all) would side with Spash (2007, 2011) in his vigorous critiques against the CBA approach of the Stern review on climate change and against the UNEP TEEB project (*The Economics of Ecosystems and Biodiversity*), and also in his call for an ecological economics that definitively breaks away from neoclassical environmental and resource economics (Spash, 2012).

Debates on fictitious money valuation and weak sustainability have accompanied ecological economics from its inception. In the early years, the identity of this field that considers the economy as a subsystem of the environment, and not as the simple application of conventional economics to

environmental issues (as in “transport economics” or “agricultural economics”), was preserved through episodes such as David Pearce’s withdrawal as one main editor of the journal and Daly’s resignation from the board of the Beijer Institute in Stockholm that had given itself the name of “ecological economics” while promoting mainstream economists.

In the 1990s, there remained however in the Beijer Institute of Ecological Economics, as a junior researcher, one of A.M. Jansson’s students, the ecologist Carl Folke (H.T. Odum’s intellectual “grandson” so to speak). In due course the Resilience Alliance was born in Stockholm with C. S. Holling’s support. The notion of resilience (the capacity of a system to withstand or recuperate from disruption) came to dominate in ecology and in ecological economics over the simpler notion of carrying capacity.

Ecological economics is not committed to a unique type of value expressed in a single numeraire or unit of account. "The issue is not whether it is only the market place that can determine value, for economists have long debated other means of valuation; our concern is with the assumption that in any dialogue, all valuations or "numeraires" should be reducible to a single one-dimension standard" (Funtowicz and Ravetz, 1994: 198). Ecological economics encompasses money-valuation, and also physical appraisals of the environmental impacts of the human economy measured in their own physical numeraires. It also gives importance to social indicators.

Nature provides resources for the production of commodities and it also provides environmental amenities. As shown by Gretchen Daily (1997), De Groot (1992) and other authors, nature, more importantly, gives gratis essential life-support services such as the cycling of nutrients, the water cycle, soil formation, climate regulation, conservation and evolution of biodiversity, concentration of minerals, dispersal or assimilation of pollutants, and diverse forms of useful energy. Controversial attempts have been made to assign money values to the annual flows of environmental services, to compare them to GDP in monetary units of account (Costanza et al., 1997). For instance, the cycling of nutrients (nitrogen, phosphorous) in some natural systems may be given a plausible money value by comparison with the costs of alternative human-made technologies. Could this same methodology (i.e. the cost of alternative technology) be applied consistently to the valuation of biodiversity in a kind of science fiction Jurassic Park framework? For biodiversity, money valuation has taken a completely different tack, namely the small sums exchanged in some "bioprospecting" contracts, or fictitious subjective money values in terms of "willingness to pay" for conservation projects, i.e. the so-called Contingent Valuation method.

For instance, how to count the service that nature provided us by concentrating minerals which we disperse? ("Exergy" costs have been calculated by industrial ecologists, but the technology for creating mineral deposits does not exist). Therefore, the figures obtained for the money values of environmental services provided free by Nature are incongruous. They are useful, however, in stimulating the debate on how "to take Nature into account".

Ecological economics rests on a foundation of "weak comparability of values" (O'Neill, 1993; Martinez-Alier, Munda and O’Neill, 1998). One simple example: let us assume that a new large garbage dump must be built near a city, and that there are three possible locations, A, B, C, one of which will be sacrificed. In our example, the three different locations are compared under only three different types of value: value as habitat, value as landscape, and economic (monetary) value. Location A is a most valuable publicly owned wetland (valuable as habitat or ecosystem because of its richness of species) but a monotonous landscape, much visited by bird-watchers (and, as such, of some economic value according to the "travel cost method"). Location B is an old agricultural area of beautiful derelict orchards and ancient manor houses, which ranks first as landscape, but only third as rent-producing, and second as ecosystem or habitat. Location C produces much rent as industrial and urban land, and therefore ranks first in economic value, but ranks only third as an ecosystem or habitat, and comes second as landscape (because of its historical qualities). Which location should be sacrificed? Should and could all values be reduced to a super-value, so as to achieve strong comparability, and even strong commensurability (cardinal measurement)? In the example, the economic values (in actual or fictitious markets) of all three locations have been taken into account, but there is no super-value (economic or otherwise such as for instance net energy production by which the wetland would presumably come out on top). Certainly, the present rankings could be reconsidered. Thus, the landscape value of A could be upgraded, and its economic value (as also that of B) could also

be increased by contingent valuation. Giving more weight to some criteria than to others, or "veto thresholds" for some criteria such as the "endangered species" provision in American legislation, or the introduction of more locations or more criteria, would help us to escape from the deadlock. The point is to show the meaning of "weak comparability of values". The decision-making process need not be irrational (by lottery, for instance).

In contrast to such multi-criteria approach, in CBA the projects to be evaluated are all valued in the same numeraire (present value in money terms of costs and benefits, including monetarized externalities and environmental amenities).

In microeconomics, there is strong comparability of values, and indeed commensurability, when externalities are internalized into the price system, as in the definition of a Pigovian tax as the economic value of the externality at optimum pollution level. In macroeconomics, El Serafy's early and influential proposal to "green" the GDP (in Costanza, 1991) -the results of which will depend on the chosen rate of interest- implied commensurability in money terms. According to El Serafy, not all receipts from the sale of exhaustible resources ("natural capital") should be included in GDP, only one part should be included, "true" income, and the rest should be counted as "decapitalization" or the "user cost" of such "natural capital" which should be invested at compound interest over the period until the resource is exhausted (as in the Norwegian Oil Fund), so as to allow the country to live at the same standard of living even when running out of the resources. How such a Fund can continue to give income if the world runs out of oil is something of a mystery. The proposal, related to Hotelling's rule in resource microeconomics, is aimed at correcting the macroeconomic accounts. It is based on a notion of "weak" sustainability only that allows the equivalent substitution of financial or manufactured capital for so-called "natural capital" -implying therefore a common unit of measurement, i.e. money value- while "strong" sustainability refers to the maintenance of physical natural resources and services.

The so-called "Environmental Kuznets Curve", an inverted U-curve, relates income and some environmental impacts. It has been much debated in ecological economics. For instance, in urban situations, as incomes grow sulfur dioxide emissions first increase and then decrease while carbon dioxide emissions and domestic waste increase with incomes. If something improves and something deteriorates, one reaction from the conventional economist might be to put weights or prices on such effects, in the pursuit of commensurability. However, the uncertainty and complexity of such situations (sulfur dioxide may counteract the greenhouse effect on temperature), and the fact that the price of externalities would depend on the outcome of ecological distribution conflicts, implies that the economist's accounts would be convincing only for the believers of the same school.

When the pattern of use of environmental resources and services and the burdens of pollution are shown to depend on changing social structures and on power and income distribution, then we enter the field of political ecology which studies ecological distribution conflicts. Economic growth leads to increased environmental impacts, and to increased conflicts (often outside the market sphere). Hence the growth of a global environmental justice movement (Guha and Martinez-Alier, 1997; Martinez-Alier, 2002). Examples abound of the failure of the price system to indicate such environmental impacts, or (in K. W. Kapp's terms) examples abound of cost-shifting successes. Thus the pattern of prices in the economy would be different without the free access to carbon sinks. Should restrictions be imposed on the "ecological footprint" of rich economies or on the HANPP (see below)? Free use of sinks was modeled in a neo-Ricardian or Sraffian framework by Perrings (1987) and O'Connor (1993) showing how the pattern of prices in the economy would be different assuming different outcomes for ecological distribution conflicts.

Related to economic valuation, some remarks are still needed on the discount rate. Economists explain discounting of the future by subjective "time-preference", or because economic growth per capita caused by today's investments, will make the marginal utility of consumption lower for our descendants than it is for us today. We discount the future because we assume that the future will be more prosperous, and therefore we destroy more exhaustible resources today and we pollute more than otherwise would be the case, thereby undermining future prosperity. This has been called the “optimist paradox”.

Even accepting the (Ramsey) argument that discounting arises from the productivity of capital, but taking also into account that such "productivity" is a mixture of true increases in production and of environmental destruction, then the discount factor should be the per capita rate of sustainable economic growth, subtracting therefore the destruction of environmental resources and services and the negative effects of pollution. Now, in order to determine the present-economic-value of such future effects caused by economic growth (loss of biodiversity, filling up of carbon sinks, production of radioactive waste...), we need not only to put money-figures on them (as discussed above), we need also a discount rate. Which?

The current debate on valuation in an intergenerational context goes back to the "socialist calculation debate" started by Otto Neurath and Ludwig von Mises in Vienna in the early 1920s. Otto Neurath (1882-1945) favoured a *Naturalrechnung*, accounting in physical terms, while Von Mises wrote that without prices there could not be a rational economy. Max Weber agreed with Von Mises. Otto Neurath disagreed, and asked how should we decide whether to use more coal now and less human labour, or keep coal for the future and use now more human labour. In today's terms, should we use more fossil fuels now, enjoy economic growth and produce more GHG, rely on technical change and invest in new renewable technologies and geoengineering, or should we go into a steady-state economy after a period of slight degrowth in the rich economies? Collectively, these are technical-ethical questions, they are not decisions that real or fictitious market prices can solve. We cannot enter into market-like negotiations with future generation of humans (or with other species); the methodological individualism of orthodox economic theory breaks down here. Nevertheless, instead of engaging with such arguments, Hayek (1952) in *The Counter-Revolution of Science*, pursuing his thirty-year old disagreement with Neurath, lumped him and other authors (Soddy, Geddes, Mumford) who supported physical accounting into the category of "social engineers", would-be dictators.

8. **Property rights and resource management**

Many years later, one article by Vatn and Bromley (1994) titled *Choices without prices without apologies* explained why money valuation is only optional. Choices depend on socially molded preferences that depend on institutions, that is, the social rules and norms. As Veblen famously put it, the individual consumption of the rich is guided by the social rule of showing off. Bromley and Vatn are institutionalist economists, in Veblen's and Kapp's tradition (while Kapp himself was influenced by Otto Neurath's economics). They see economic behaviour not as being determined by inscrutable individual preferences but as influenced and explained by social rules and norms. Institutions articulate a diversity of values (Vatn, 2005).

In this context, Coase's approach to the internalization of negative externalities or positive environmental services into the price system relies on market transactions between partners. So, if an agent (a peasant community, a factory) pollutes the water in a river, the downstream aggrieved agents may get together either to ask for an indemnity equivalent to the damage suffered or to bribe the polluters to stop the pollution, depending on the property rights on the river. This might work without need for government intervention. However, getting the downstream people together to start a court case implies "transaction costs" (lawyers' fees, time for meetings) which prevent the simple market solution from operating, as Coase himself emphasized. Moreover, when those being polluted are future generations and other species, the market solution does not operate. Regulation (physical norms and fines) or Pigovian taxation are preferable.

Regarding the empirical study of a very popular policy instrument such as Payment for Environmental Services, one main contribution from ecological economists has been to criticize the simple Coasean, market approach, and introduce complexities related to uncertainty, distributional issues, social embeddedness, and power relations, acknowledging the variety of contexts and institutional settings in which PES operate (Muradian et al, 2010).

The institutionalist perspective (economic actions are explained by social rules more than by inscrutable individual preferences) is very relevant for the study of the relation between property rights or property regimes and the management of natural resources. We go back here to the much quoted article by Garrett Hardin (1968), *The Tragedy of the Commons*, which should have been titled "the tragedy of open access". Hardin attended the inaugural conference of the ISEE in Washington DC and he had a chapter in the seminal book edited by Costanza (1991). One paragraph in Hardin's article starts like this: "Picture a pasture open to all…", and describes how a tragedy of overgrazing will occur

because individuals would put more and more sheep or cows on the pasture provided that the marginal benefit (a few litres of milk, a few pounds of wool, some sacks full of dung) would be larger, individually, than the private marginal cost, disregarding the collective marginal costs in terms of soil degradation.

To the old liberal critique of "common" property ("the magic of private property (and enclosures) would turn sand into gold" had written Arthur Young) was now added a trendy environmental critique, the Tragedy of the Commons. However, was Hardin not aware of the rules that in the past (brought from England to New England) presumably regulated the amount of horses or cows that a citizen could put to pasture in the Boston Commons? Or in any other commons in the Americas, whether a Mexican ejido or a New Mexican common pasture? Why was the confusion between "commons" and "open access" not spotted by the reviewers of Hardin's article in *Science*? There were many well regulated communal systems of management for forests, coastal fisheries or irrigation water, as Bromley and others soon retorted and as Elinor Ostrom was to study in detail (Ostrom, 1990).

Hardin's 1968 article mistook commons for open access. It preached privatization (or state property) against the misnamed "commons". It took some time until the confusion was cleared up, provoking much research on the functioning of common property regimes, and also on the relations between forms of property and resource management. There are certainly open access resources, for instance some fisheries in the open seas. The atmosphere was also treated as being in open access to dump polluting substances such as CFC that damage the ozone layer until an international treaty banned this practice. The atmosphere is still a dumping ground in open access as regards GHG. Other examples abound. But apart from open access (which should be avoided), there were other forms of property.

- The true commons
- Private property
- State and municipal property

Some scholars did research on the trend to turn natural resources held in common and subject to traditional management rules (like coastal mangroves and fisheries in India or Latin America) into de facto private property, e.g. for growing shrimp or for fishing for export. This was described not only as a social but also an environmental "tragedy of enclosures".

Compared to open access, private property is in principle more conducive to conservation because the costs of today's actions will be felt by the owner or his immediate kin. This was discussed in resource economics at least since Faustmann's rule (1849). The private owner of a forest (or rather, of a tree plantation) will decide to cut the trees not as soon as possible, but when the rate of growth of the trees (net of harvesting costs and multiplied by the market price of wood) falls below the rate of interest in the bank plus the rent to be obtained from the land now empty of trees (potentially used for crops or pastures while the new stand of plantation trees is starting to grow again). Notice here that a high interest rate (or discount rate) will lead to cutting the trees very soon, while payment for ecosystems products or services (like hunting rights, mushroom collection, recreation under the trees, carbon capture) would slow down the rotation period and could even persuade the owner not to cut the trees at all and eventually turn back the plantation into a true forest.

In the case not of trees in a plantation but of extraction of mineral ores or fossil fuels, private property linked to the profit motive is certainly not conducive to conservation, nor to the avoidance of negative environmental impacts after the exhaustion of the resource such as acid drainage from mines. An oligopoly such as OPEC slows down oil extraction because of economic and not environmental objectives. New institutions, that is, rules articulating new values (for instance, civil or criminal legislation on socio-environmental liabilities) would perhaps modify the behavior of the extractive industries.

9. Social Metabolism and Indexes of (Un)sustainability

Because of the shortcomings of money valuation, ecological economists favor physical indicators and indices in order to judge the overall impact of the human economy on the environment. Therefore, we leave here aside monetary corrections to GNP, such as El Serafy's (see above), or Hueting's (in Costanza, 1991), which calculated the economic costs of adjusting the economy to socially negotiated

norms or standards of pollution and resource extraction, in a "cost- effectiveness" approach (by "cost-effectiveness" is meant the analysis of the cheapest way, in money terms, in order to adjust the economy to such physical norms or standards). We also leave aside the ISEW (see above) whose end-result is a figure in money terms commensurate with GDP though often showing quite a different trend.

According to Georgescu-Roegen (1971), economics should see the economy as an open system (and not as a self-sustaining system, a "merry-go-round" between consumer and producers as in the textbooks). Economics should study the "metabolic flows" in the economy. This is today linked to two research schools. The first one centres on Marina Fischer-Kowalski's collaborators at the Institute of Social Ecology in Vienna, drawing on work by Robert Ayres, R.P Sieferle and other authors. This group has developed methods for the study of the social metabolism, listed below.

The second school would be Marxist ecological economics. It has much less influence. It claims with reason that Marx already wrote in the 1860s that the capitalist economy was causing a "metabolic rift" (Foster, 1999) between humans and nature. Marx took the work metabolism (*Stoffwechsel*) from Moleschott and Liebig, pointing to the export of nutrients in the soil by commercial agriculture. Capitalism not only exploited workers it also exploited the soil. The soil was no longer a "fund" able to supply crops continuously; it became an exhaustible stock in terms of its fertility and texture. Marx quoted Liebig who feared the day when guano imports would diminish. Marx, as Liebig, hoped for factory-made chemical fertilizers (in a sort of "weak sustainability" approach) to escape the Malthusian trap of "diminishing returns". Despite such intellectual traces, a Marxist ecological economics or environmental history has not existed until the end of the 20th century from Altvater (2007), Bellamy Foster, Hornborg (in his theory of ecologically unequal trade, Hornborg, 1998), and O'Connor's "second contradiction" (O'Connor, 1988).

Going back to the first school, here is a summary of today's methods for the study of social metabolism trying to ascertain the trends in the use of materials and energy in the economy. They allow concrete answers to questions such as, "is the economy dematerializing in absolute terms, or only relatively to GDP growth", "has the human appropriation of biomass increased as fast as population in the last hundred years", "is the energy cost of obtaining energy increasing"?

• Calculations of Material Flows (in tons), often divided into Biomass, Building Materials, Mineral Ores, Fossil Fuels, at national or regional levels. Therefore one can test the hypothesis of "dematerialization" of production or consumption, and one can do calculations of physical trade balance supporting the arguments on ecologically unequal trade (Perez Rincon, 2006; Weisz et al., 2006; Russi et al., 2008).

• Calculation of Energy Flows at national or regional levels including historically changing ratios of exomatic energy use / endosomatic energy use (Giampietro et al. 2013), calculations of the EROI (energy return on energy input, Hall et al., 1986). EROI calculations show whether there is a trend towards an increasing energy-cost of obtaining energy. Some anthropologists analyzed the basic economics of human society as a flow of energy (e.g. Roy Rappaport's *Pigs for the Ancestors*, 1968). Engels in 1882 discussed this topic with Marx sadly denying the relevance of Podolinsky's agricultural energetics for Marxian economics. Max Weber in 1909 had criticized Wilhelm Ostwald's interpretation of economic history in terms of a) an increased use of energy, b) an increased efficiency in the use of energy, because economic decisions on new industrial processes or new products were based on prices, entrepreneurs did not pay attention to energy accounts per se. Max Weber did not yet question energy prices from the environmental point of view as we would today. In the 1970s David Pimentel (Pimentel et al., 1973) showed the decreasing energy efficiency in maize cultivation in the United Sates. A new field was opened up by such studies on the efficiency in the use of energy in different sectors of the economy, including the energy sector itself.

• Calculations of "virtual water" in import or in exports (e.g. wheat, soybeans, meat, ethanol, cellulose) at regional or international levels, i.e. the water "dissipated" in growing crops, pastures, timber. It was argued by Tony Allan in the 1990s that water disputes in the Middle East were mitigated by importing food. Hoekstra and Chapagain (2007) have calculated water footprints of nations, and there is research on the unpaid water transfers embodied in trade in commodities.

• Calculations of HANPP, the Human Appropriation of Net Primary Production (including the "embodied HANPP" which is relevant for trade statistics) (Vitousek et al., 1986; Kraussman et al., 2013). The driving idea is that the larger the amount of potential biomass production appropriated by humans in a given territory, the less biomass is available for other (non-domestic) species, and therefore the more likely the loss of biodiversity. The proportion of NPP appropriated by humans is increasing because of increasing demands of land for urbanization and infrastructures, for growing feedstuffs and agrofuels, for growing timber.

All the indexes mentioned above are measured in different units and might show different trends although there are also some rules of congruence among them. There are no cases of rapid GDP growth and persistent degrowth in Material Flows (particularly when trade effects are taken into account). But it might happen that increasing fossil fuel inputs into agriculture will increase yields and slow down the increase in the HANPP. How should a situation be judged in which, for instance, an index such as MF slightly improves while HANPP deteriorates, EROI decreases, GDP grows, infant mortality decreases, and self-reported life satisfaction is stable? Notice that the HDI (human development index) regularly published by UNDP adds up economic and social indicators into a single number but it does not include environmental impacts at all. Commensurability would imply reducing such values to an encompassing super-value but this is not necessary in order to reach reasonable integrated assessments by macroeconomic multi-criteria evaluation (Shmelev, 2012).

There is one composite physical index of (un) sustainability that was born within ecological economics and has had great success in public opinion: the Ecological Footprint, first presented by Bill Rees (an ecologist turned urban planner) around 1991. Which is the environmental load of the economy, in terms of space? H.T. Odum had posed the question, and later authors developed some answers. Rather than asking what maximum population a particular region or country can support sustainably, the question becomes: how large an area of productive land is needed (as source and sink) in order to sustain a given population indefinitely, at its current standard of living and with current technologies? The Ecological Footprint is the inverse of the carrying capacity (see below). Computations, not only for cities or metropolitan regions (whose "ecological footprint" is hundreds of times larger than their own territories) but for countries, show that some densely populated European countries or Japan and Korea (assuming per capita eco-footprints of 2 or 3 ha) occupy eco- spaces ten times larger than their own territories (Wackernagel and Rees, 1995). The Ecological Footprint is rightly criticized because it adds up actual land use (say, one hectare per person for food, feed and timber) and notional or "virtual" land use (say, another hectare) for the absorption by photosynthesis of the carbon dioxide produced by burning fossil fuels. The results are sometimes expressed in terms of how many real plus virtual planets humankind is using, already we are using one and a half. But this depends on the amount of land that is left for other species. If the HANPP would be reduced by half for that purpose, then the Ecological Footprint of humans in terms of extra planetary needs would be even more alarming. Despite these and other critiques, the Ecological Footprint has enjoyed great success possibly because a spatial representation of environmental impact is easily understood.

10. On population

Ecological economists emphasize both the pressure of population and the pressure of production (and consumption) on resources. How large is humankind's ecological footprint? Has humankind exceeded "carrying capacity"? This is defined in ecology as the maximum population of a given species, such as frogs in a lake, which can be supported sustainably in a given territory without spoiling its resource base. However, the large differences internal to the human species in the exosomatic use of energy and materials, mean that the first question is, maximum population at which level of consumption? Second, human technologies change at a quick pace. Already Boserup's thesis (1965) of endogenous technical change according to which pre-industrial agricultural systems had intensified in response to increases in population density, tried to turn the tables on the Malthusian argument. Third, the territories occupied by humans are not "given", other species are pushed into corners or into oblivion (as the index HANPP implies), and, internal to the human species, territoriality is politically constructed through state borders. Fourth, international trade (similar to horizontal transport in ecology, but which humans can regulate consciously) may imply "ecologically unequal exchange", though if one territory lacks a very necessary item which is abundantly present in another territory, Liebig's law of the minimum would recommend exchange. Then, the joint carrying capacity would be larger than the sum of the carrying capacities of all autarchic territories.

Because of the shortcomings of "carrying capacity" as an index of (un)sustainability for humans, and because of Barry Commoner's arguments against Paul Ehrlich's fixation on population growth (Ehrlich, 1968) allegedly forgetting that overconsumption was the main environmental threat, the formula I=P.A.T was proposed by Ehrlich himself, where I is environmental impact, P is population, A is affluence per capita, and T stands for the environmental effects of technology. Efforts are being made to operationalize I=PAT. True, population remains one important variable. True also, the demographic transitions are not mere automatic responses to urbanization and education, and their timing does not depend only on inheritance patterns and family forms. Human demography is anticipatory and self-conscious. Though it also follows Verhulst's curve, it is different from the ecology of a population of frogs in a lake.

There have been three different varieties of Malthusianism. First, Malthus' own view in 1798 that human populations would grow exponentially unless checked by war and pestilence, or by the unlikely restraint of chastity and late marriages. Food would grow less than proportionately to the growth of the labor input, because of decreasing returns. Hence, subsistence crises.

Then there was the Neo-Malthusianism of 1900, with radical activists such as Emma Goldman, Paul Robin (Ronsin, 1980). Human populations could regulate their own growth through contraception. Women's freedom was required for this, and it was desirable for its own sake. This was a feminist Neo-Malthusianism, insisting on what is called today "reproductive rights". Abortion and vasectomies should not be criminalized. "Conscious procreation" was required in order to prevent low wages and pressure on natural resources but the main cause of poverty was social inequality. This was a successful bottom-up movement only in some parts of the world, particularly in Europe and America against States (which wanted more soldiers) and against the Catholic Church.

There is finally top-down Neo-Malthusianism after 1970, reaching extremes like Hardin's "lifeboat ethics" (Hardin, 1974) against freedom of migration with racist overtones. This top-down doctrine and practice is sponsored by international organizations and some governments. Population growth is seen as one main cause of poverty and environmental degradation. Therefore states must introduce contraceptive methods, even sometimes without the populations' (particularly women's) prior consent.

Ecological economists have been divided into top-down and bottom-up Neo-Malthusians with lack of dialogue between them although they all refuse the doctrines of the anti-Malthusians, who assume that human population growth is no threat to the natural environment, and that it is conducive to desirable economic growth. Ecological economists believe that growth of world population (four times in the 20th century) is certainly a very major issue. It now seems that population might be stabilized and even go into a slow decline after 2050, at less than 9 billion people. This is welcome. Fertility is going down in many regions and countries. The demographic transition is being completed. This is a good thing, although local depopulation (not only rural, also urban) may create new social and environmental problems.

11. Civil Society and Ecological Economics

There is no doubt about the present influence of the main schools of economics on governments and public opinion (perhaps except for Marxism but certainly including Keynesianism, Schumpeterian economics, neoliberal or market fundamentalism…). But one can doubt still whether ecological economics is having any influence at all. Who and where are the non-academic "consumers" of ecological economics?

So far, despite the overarching vision of Georgescu-Roegen and his followers, no politician ever quotes in public debate the entropy law and its relevance for the economic process while many discuss the large or little ups and downs of GDP, and the public debt risk ratings. Detroit's municipal default of 2013 seems more relevant to both neoliberal and Keynesian public opinion leaders in rich countries than the world ecological debt. Nevertheless, the critiques of national income accounting by ecological economists and by eco-feminist economists have certainly influenced the sporadic and rather fruitless movements to move "beyond GDP" by governments and international bodies. It is obvious that many caring activities in families and in society and many services of nature (Waring, 1988), remain outside the market, and therefore are unaccounted for although they are essential for social reproduction and human well-being. This is commonly accepted. Further, a civil society group in the United States (CASSE) is promoting

the steady-state economy. Its motto is: "Growth, especially in wealthy nations, is already causing more problems than it solves". It has over ten thousand members.

Meanwhile, the economic valuation and payment for ecosystem services has become a growth industry in Ministries of the Environment and Forests, worldwide. Also, trends of the de-carbonization of the economy and also of its material intensity are mentioned in political debates in some countries. But there is an enormous gulf between the critiques from ecological economics and current government and business practices. Business circles are, like governments, eager consumers of economic doctrines but they ignore ecological economics. At most, the debates on the environmental liabilities from private or public companies, also known as "the social costs of private enterprise" (Kapp, 1950), have given rise to so far aimless discussion of how to take the environmental damages into the actual accounts beyond "greenwashing" corporate social responsibility exercises (Sukhdev, 2012). Moreover, some legal avenues to claim environmental liabilities from companies (such as the ATCA legislation in the United States) are closing down.

Other notions from ecological economics, such as ecologically unequal trade, have been taken up by environmental groups from the South, especially by "post-extractivist" groups in Latin America. For instance, the metabolism of soybean production (loss of soil nutrients and "virtual" water"), and the damage from glyphosate spraying in Monsanto GMO crops, is a growing issue in the politics of Argentina (Pengue, 2005).

Via Campesina is an international network of peasant and landless workers' organizations. Drawing on studies of the energetics of the modern food systems, it claims that traditional peasant agriculture cools down the Earth. Viceversa, concepts like the ecological debt or carbon debt have progressed from activist circles to the speeches of ministers or even heads of state from some countries in the South, and then to academic journals (Srinivasan et al., 2008). Similarly, concepts like Degrowth get support from social movements (the *Décroissance* movements in Europe), easily connecting to Jackson's and Victor's academic ecological macroeconomics without growth. The European Ecological Economics Society (a very active branch of the ISEE) supports the activist and academic conferences on Degrowth (not without internal debate), a position very unlikely to be taken and for good reasons by the Indian Ecological Economics Society. The reception of and contributions to ecological economics by civil society organizations has been researched by Healy et al. (2012).

For instance, on a new issue like geoengineering (combating climate change through ocean iron fertilization, sulfate aerosol spraying…), although the ISEE will not take a political position, already a well known Australian ecological economist, Clive Hamilton (2013), has provided something like the ecological economist's party line (which is similar to that anticipated by Pat Mooney of the civil society organization ETC), showing that geoengineering is fraught with new dangers, that the precautionary principle should be applied, that the debate should be opened up as in the "post-normal science" approach (Funtowicz and Ravetz, 1994), and that climate change mitigation in the form of reducing emissions is preferable to such doubtful experiments with uncertain consequences. Ecological economists will differ among themselves, however, on the measurement of costs of climate change mitigation, and even on the proper units of account of such costs.

12. The Society for Ecological Economics

Could the ISEE (born in the late 1980s) be seen in future as remotely similar in influence (though very different in intention) to the Mount Pelerin society founded by Hayek in 1947 to defend the market economy and Karl Popper's "open society" against Marxist doctrines and Keynesian social-democratic planning? Should the ISEE have a political objective? Is the pluralism in ecological economics undermining such a prospect, or rather, is it the radicalism of ecological economics preventing or delaying its social acceptance? Should we relent a bit and accept "weak sustainability" and the promises of ecological modernization, or should we denounce UNEP's "green growth" of 2013 as an oxymoron even more blatant than Brundtland's "sustainable development" of 1987? In fact, should "we" (ecological economists) have any collective position at all?

The ISEE has lived up to its promise of promoting a transdisciplinary field at the intersection of ecology and economics. Both economists and ecologists coming from different schools have been active in the field. This article has briefly explained the origins of ecological economics going back to the late 19th century. Therefore it is not true that "ecological economics is simply what ecological

economists do". They do many different things but within a common tradition which is not clearly delimited because it is at the interface of related fields.

While the journal *Ecological Economics* and the biennial conferences are the main focus of activities of the ISEE, there are active regional societies in the United States, Europe, India, Latin America, Russia. The European Society for Ecological Economics edits also another journal, *Environmental Policy and Governance.* The Latin American ecological economists publish the journal *Revibec*. Well known ISEE members have edited related journals: Charles Perrings, *Environment and Development*; Clive Spash, *Environmental Values*; Robert Costanza, *Solutions*; Jeroen van den Bergh, *Environmental Innovation and Societal Transitions.* The Indian Society (INSEE) regularly publishes proceedings of well attended conferences. Her past-president, Kanchan Chopra, gave her name to a famous committee mandated in 2002 by the Supreme Court, giving the methodology for calculating Net Present Values of non-market forest products and services sacrificed by mining or hydroelectric projects.

Among all this variety, there is a common thread. A sample of first university degrees and main scientific interests of the (older) ecological economists can be constructed by listing the names of the ISEE presidents since 1989, as follows.

- Robert Costanza, systems ecology, architecture, energy in the economy, ecosystem services
- R.B. Norgaard, economist, post-development studies, co-evolution, biodiversity conservation
- John Proops, physicist, energy in the economy, capital theory, economic-ecological modeling
- Charles Perrings, economist, development studies, economics of biodiversity
- Joan Martinez-Alier, economist, energy in society, environmental history, political ecology
- Peter May, resource and environmental economist, development, Amazon deforestation
- John Gowdy, economist, economic anthropology, economics of consumption
- Bina Agarwal, economist, development and feminist economics, common property, India
- Marina Fischer-Kowalski, sociologist, industrial ecology, social metabolism, transition societies

This can be complemented by the list of recipients of the ISEE Boulding Award: Herman Daly (economist), Robert Goodland (biologist), A. M. Jansson (ecologist), Robert Costanza (ecologist), C. S. Holling (ecologist), Robert U. Ayres (physicist, industrial ecologist), Partha Dasgupta (economist), K. G. Mäler (economist), R. B. Norgaard (economist), Charles Perrings (economist), Manfred Max-Neef (economist), Ignacy Sachs (economist), Joan Martinez-Alier (economist), Bill Rees (ecologist) and Mathis Wackernagel (ecologist), roughly divided by half into ecologists (biologists, physicists) and economists according to their original training. Their names have often appeared in the present article.

Ecological economics is then a new transdisciplinary field which studies topics and applies methods such as:

-new indicators and indices of (un)sustainability of the economy;
-ecological macroeconomics without growth, the debate between "weak" and "strong" notions of sustainability;
-the application of ecological notions of carrying capacity and resilience to human ecosystems;
-the valuation and payment for environmental services, monetary valuation of externalities but also the discussion on incommensurability of values;
-risk assessment, uncertainty, complexity and "post-normal" science; integrated environmental assessment, including building of scenarios, dynamic modeling, participatory multi-criteria methods of decision making;
-the allocation of property rights and its relation to natural resource management, old and new communal institutions for environmental management;
-environmental causes and consequences of technological change, relations between ecological economics and evolutionary economics;
-theories of consumption (needs, satisfactors), as they relate to environmental impacts;
-relations to industrial ecology; applications to business administration; corporate liability and accountability
-relations to fields such as feminist economics; environmental and economic history; environmental ethics; political ecology, urban planning, peasant studies;
-environmental public policies, instruments of environmental policy often centred on the "precautionary principle" (or "safe minimum standards", as introduced by Ciriacy-Wantrup).

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