Resources, lifestyles and shared wealth: thoughts about a prosperous way down

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I speak for the trees, for the trees have no tongues
(The Lorax, Dr. Seuss, 1971)

Abstract

Shared resources (natural capital and ecosystem services, i.e. the so-called Commons) play a fundamental role within the complex network of relationships that ensure functioning and resilience of ecosystems and human economies. It is crucial to ascertain to what extent these resources are best used for the common benefit and, if not, how this could be implemented. Money-based schemes for valuing the Commons, such as the so-called "willingness-to-pay", provide a user-side evaluation perspective based on the idea that value only stems from utilization by humans. Proper management of natural capital and environmental services requires, first of all, that a new value system is adopted, a system that recognizes that they cannot be only evaluated in money terms. We present in this paper a supply-side evaluation method based on the idea that a comprehensive measure of value can be achieved by accounting for the work done by nature in generating services and resources (Emergy Synthesis; Odum, 1996). Within this framework, the rate and intensity of resource generation and turnover become a major constraint for their sustainable use by the present and future generations. Secondly, it should not be disregarded that resources and environmental services also provide support to other species in the web of life, which share the same "ownership rights" as humans do. Wealth generation out of the Commons should therefore be transparent, equitable, assessed by means of agreed upon criteria, and finally should feedback and reinforce the upstream processes that generated them.

Keywords: Commons, Natural Capital, Ecosystem Services, Emergy, Environmental Policy.

1. Introduction: A tale of growth and descent

A large number of studies have warned us about the turndown ahead, suggesting models, policy tools, limits to growth, and alternative lifestyles. While the present energy and resource exploitation mostly supports the welfare of a minority of wealthy people in developed and developing countries, the environmental degradation related to such welfare affects the majority of world population, left without the primary resources and services necessary to secure their present and future well being. The unsustainability of the growth paradigm appeared during the 1970s, proposed by the Club of

Rome and by intellectuals such as Nicholas Georgescu-Roegen, Jean Baudrillard, André Gorz and Ivan Illich, among others. The concept was further developed, enriched and rooted in thermodynamics, economy and philosophy by a large number of contemporary economists, scientists and intellectuals.

The Limits to Growth

When Meadows et al (1972) presented their Report "Limits to Growh" it was a shock to many. The population of the planet was at that time about 3 billions and half. We are now close to 7 billions and still growing. Some say that since the peaking and downturn that was predicted did not happen, Meadows *et al* were wrong. This is not true, unfortunately. The growing population coupled with the increased consumption driven by more affluent life styles is generating an unsustainable load on available resources. The environment as a source of resources and as a sink of waste is limited. Alarming signs of stress are everywhere, not just in climate change.

Business-as-usual

Advocates of business-as-usual (i.e. of keeping the present growth rate unabated) suggest that what is needed to maintain a growing economy is increased efforts to extract more energy from deeper reservoirs, oil sands, nuclear. They seem to disregard the declining net energy of these sources (increased effort means increased energy investment and less net energy). Other alternative solutions that have been suggested (increased efficiency, biofuels, other renewable energy resources) are also affected by low net energies and small return on energy investment.

However, let's assume that we are able to meet, by means of renewable energies, the world fossil energy demand and that we can therefore run the economy without any significant downsizing. A business-as-usual economy, even if supported by solar energy, would still mean billions of cars, large fractions of land covered by roads and parking lots, huge extraction of minerals for industrial activities, large amounts of sediments moved to the oceans by agriculture, construction sector and industry, large water use, forest clear-cutting, oceanic over-fishing, and so on. Sooner or later it would clearly appear that energy and climate change are not the only problems and, maybe, not even the most important ones.

Business-as-usual is not an option for the future of humankind. The individual environmental, economic, and energy crises that societies face at oscillating intensity and that fill up the pages of the newspapers, are only the day-by-day more frequent signs of a systemic crisis of the business-as-usual model. This is not because of an intrinsic badness of the growth model, but because of the fact that unlimited growth is impossible in a limited planet and sooner or later every

activity is constrained by a limiting factor.

2. The pulsing paradigm

According to Odum and Odum (2001)'s "pulsing paradigm", all systems follow oscillating patterns of growth, climax, descent and slow restoration. Human societies grow and decline. The Roman Empire is now over and through its demise we may be able to recognize this trend. It took more than one thousand years for the whole cycle to run and about 300 years for the descent only. The longer pulsing "wave-length" makes it difficult for us to recognize the cycle of which we are part, while instead recognizing the shorter pulsing cycles of ecosystems. If human societies are regulated by the same principles as other ecosystems and species on Earth, then it would not be a good policy "to paddle countercurrent", trying to force societies to grow when resources are scarce or to descend when resources are abundant. Instead, it would be a good policy to recognize the descent ahead and begin managing for it to be prosperous. It's worth noting that according to the pulsing paradigm not even a steady state economy is possible in the long run. Sustainability is not reaching a plateau and trying to keep it stable for ever, but instead adapting our lifestyle to the unavoidable resource oscillations.

Odum and Odum (2001, 2006) do not simply refer to de-growth or less growth, but instead to unavoidable oscillating patterns tuned to, and driven by, oscillations of the available resource basis: "*Policies based on understanding could be the difference between a soft landing and a crash...Make no mistake, this is not a proposal for less growth. It is recognition that general systems principles of energy, matter, and information are operating to force society into a different stage in a long-range cycle. One set of policies is needed for the transition and another set for the descent. We can also look way ahead at a lower energy period when environmental resources accumulate again*."

The decrease of available resources (be they oil, minerals, fresh water or topsoil) is unavoidable. Efforts for increased efficiency are unlikely to provide any significant solution to the large amount of social, environmental, technological and economic problems generated by the growth, business-as-usual paradigm. We need to look towards another kind of growth, a qualitative one, in which humans may find satisfaction by less (and more effective) use of natural resources.

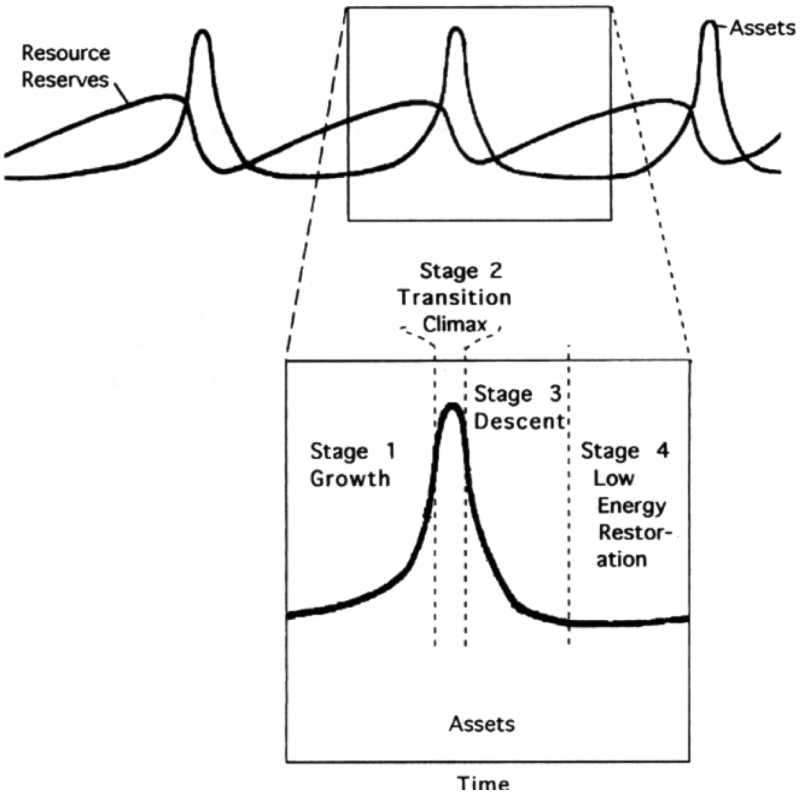


Figure 1. The pulsing paradigm (Odum and Odum, 2001)

3. Measures of wealth

Governments use money-based accounting systems of national economies to calculate macroeconomic indicators such as gross domestic product, gross national product, and per capita income, among others. In the last years, also in response to a perceived lack of comprehensiveness of such accounting systems, more attention was placed on the economic use and evaluation of the ecosystems. A recent example in this direction is the international project "The Economics of Ecosystems and Biodiversity TEEB (http://www.teebweb.org/) aimed at evaluating in money terms the contribution of ecosystems and biodiversity within the framework of productive economic systems. The term "Environmental Accounting" is most often referred to as the practice of including the indirect costs and benefits of an economic activity, for example its environmental load on health and society, along with its direct costs, when making business decisions.

Considering the almost complete decoupling of the economy and the environment that characterized the so-called mainstream (or neoclassical) economics by far, the recent recognition that human economies rely on natural resource storages and ecosystem services must be considered an

important step ahead, very likely one of the most important achievement of Ecological Economics, a modern branch of the Economic theory (Georgescu-Roegen, 1975; Costanza, 1989; Martinez-Alier, 1990; Patterson, 1998; Daly and Farley, 2004; Faber, 2008).

Point is now: What is the value of natural capital and ecosystem services? How can such a value be measured? Value for whom? No doubt that within the framework of Neoclassical Economics the value of an environmental resource is very small when the resource is abundant and starts to increase when it approaches scarcity. Several resources were not assigned any value in the past due to their relative abundance (land, pasture, fresh water) compared to demand by a smaller population. They remained as no-value "Commons" until growing population and increased use made their economic value to grow. Some "Commons", such as clean air and rain water, are not (yet) marketed and therefore they are considered worthless: as a consequence, they remain nobody's resources and are most often degraded by improper use (e.g. polluted by chemical emissions). Other resources such as land, forests and fresh water storages can more easily be limited and marketed, so that they are being assigned monetary values. Worth mentioning as a typical case of misused commons, the trend towards privatization of water and improper use has been clearly indicated as unacceptable practice by the United Nations in its 64th General Assembly on 28 July 2010, declaring access to clean drinking water and sanitation as a human right (UNO, 2010).

A large number of studies have already warned about the turndown ahead, suggesting models, policy tools, limits to growth, and alternative lifestyles (Hubbert, 1949; Meadows et al., 1972; Capra, 1982; Tainter, 1988; Odum and Odum, 2001; Heinberg, 2009). Moreover, while the present resource exploitation mostly supports the welfare of a minority of wealthy people in developed countries, the environmental degradation related to such welfare affects the majority of world population, left without the primary resources and services necessary to secure their present and future well being. Hardin (1968) referred to the degradation of common resources as to an inexorable "tragedy of commons". Barnes (2006) claims that there is no reason for which the "Commons are inexorably "*fated to self-destruct*" and suggests Commons – the inheritance received by nature and by previous generations – to be maintained over time by revising the dynamics of global markets. He suggests new actors (independent Trusts) to operate in favor of the other species, the global environment and future generations. Barnes identifies "three forks" of the Commons river, i.e. the main pathways for the formation of Commons: Nature, Community and Culture (Figure 2). According to such an identification, Barnes listed a large number of products, services and infrastructures that are generated by Nature or by the common effort of entire societies and that in turn become a source of additional value and wealth. Internet and the stock market are two examples of infrastructures that generate value (the existence of which allows actions that

support economic and cultural processes and generate income). Creation of wealth by using the Commons is, in Barnes' opinion, something that involves property rights of all species and the unborn as well. All individuals are entitled to ownership rights by birth and should receive dividends of the wealth created. Since shared resources belong to all species on Earth and to the future generations as well, processes and systems which receive the largest benefits from their appropriation of the Commons (storages of minerals, fuels, standing biomass, fresh water, clean air, culture, information, biodiversity) should provide a proportional feedback to reinforce the resource basis. This is needed in order to prevent natural capital degradation and to ensure the resource throughput (empower) being maximized through all levels of world ecosystems and societies.

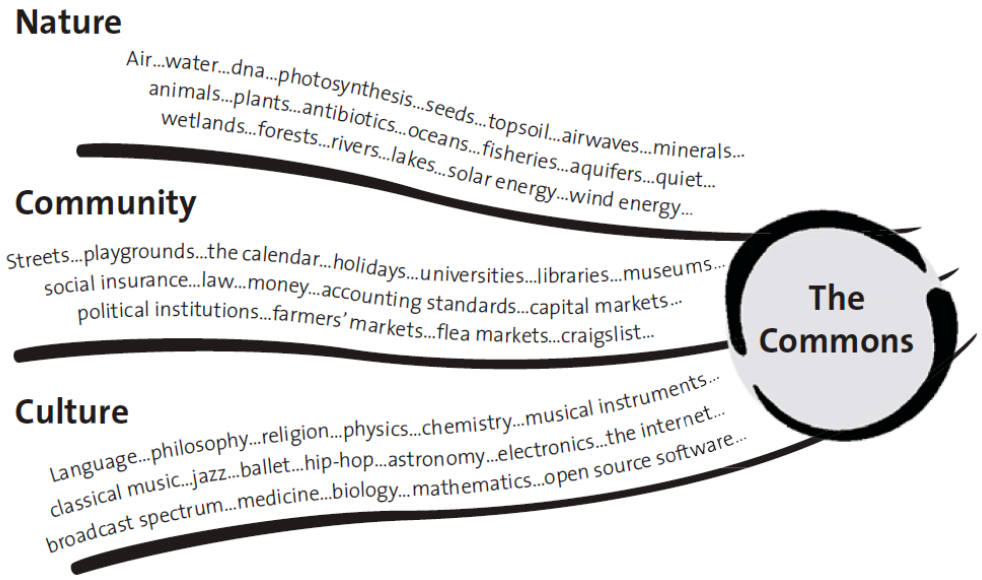


Figure 2. The three forks of the Commons river (Barnes, 2006).

The problem with the sustainable use of the Commons is that it is not easy to establish an agreed upon measure of value as the basis of economic, normative and conservation actions. Energy taxes, carbon taxes, and even the Kyoto protocol share the difficulty of identifying an agreed upon measure of value that can be used as the basis of a "policy for the Commons".

In spite of the efforts done by several Governments and the scientific community, the anthropocentric framework that still characterizes most of the economic approaches mainly focuses on and assigns value to those services that are of interest and benefit to humans, in so disregarding the fact that nature provides services to countless species different than human beings.

4. How better could shared resources be accounted for?

Each species receives from the surrounding ecosystem a series of free services (ecosystem services) and in turn supports the life of other organisms by contributing free services to them. Sustainability is guaranteed when organisms feed on flows directly available and only withdraw every year fractions of the stored resources that are smaller than or equal to the amount that is generated yearly by the ecosystem. This way stored resources are not depleted over time but act as buffers for increased stability.

Results from the Millennium Ecosystems Assessment (MEA, 2005) pointed out the role of ecosystems services to the stability of human societies and human-well being. Although such a point of view is mainly focused on human values and preferences (the user-side point of view), yet the set of ecosystems services pointed out by MEA researchers provides an important starting point for further assessments of the interplay of man and biosphere, and well-balanced interactions among all its components. The MEA effort, although certainly valuable and timely, does not provide any evaluation of the "production cost" of such services from the point of view of the biosphere.

Instead, it would be very interesting and important to test innovative frameworks and accounting methods to assess how much of the environmental work goes into providing each typology of services. Such an assessment would provide an understanding of how much is lost if the environmental service is discontinued and how much is gained if it is kept healthy and vital (Allen et al., 2003). Disregarding these aspects would dismiss the "supply-side quality" of resources, similarly to what most energy analysts do when adding joules of different nature (from fossil fuels, nuclear, sun, wood, wind, etc.), by assuming that all joules are alike and ignoring the work done by the biosphere to provide different energy sources. Odum (1988, 1996) identified the work of biosphere driven by solar, gravitational and geothermal energies as the source of environmental goods and services. He provided a common measure for such sources, namely the solar equivalent energy (emergy), pointing out that it can be used as the basis for sustainability assessments and natural capital evaluations (Odum, 1994a). The focus of the emergy accounting method is placed on the overall functioning of the geobiosphere with all its components and processes, within which human societies are embedded. Assessing the biosphere work for resource and service supply helps identify a new basis for resource management, rooted into issues of environmental sustainability and shared ownership, applicable to decision making on scales and ethical issues that cannot be dealt with by Adam Smith's "invisible hand" of the market.

5. Human-made capital and the economic system

Figure 3 highlights the dynamics of economic systems within the larger framework of the biosphere. The main environmental driving forces support the work of nature for cycling and concentrating resources (soil, wood, fresh water, minerals). The economic system invests energy, goods, labor and services in order to exploit such resources provided for free by nature. In so doing, economic activities and sectors (mining, industry, agriculture, fishery, forestry, education, health services, transportation, etc.) in turn provide products and services to the market. Exploitation of free environmental resources cannot be unlimited, in a physically-limited word. If withdrawal is faster than turnover time, the resources are depleted and used up. In order to prevent or delay depletion, investments from economy should not only support withdrawal, but also provide a reinforcing feedback to ensure the stability of the resource basis (e.g.: plant new trees after wood harvest; rotate crops in order to stabilize the content of soil organic matter and nutrients; recycle reusable materials) according to Lotka-Odum's Maximum Empower Principle (Lotka, 1922; Odum, 1996).

Economic activities release new flows and develop new storages. Oil is converted into electricity and transportation services; minerals are converted into infrastructures and machinery; electricity, machinery and infrastructures are in turn converted into educational, health and recreational services. In so doing, new storages of information are created (universities, libraries, arts and museums, know how, and, over longer time frames entire cultures, religions, languages) that in turn become the basis for further development of societal system and, at the same time, feedback to the lower hierarchical levels to expand or stabilize the resource basis.

The economic process is certainly driven by the fossil energy used, but also by the possibility to dilute the chemicals and the heat released to the atmosphere and the water bodies. The environment as a sink must be therefore considered an important driving force in itself, without which a sustainable operation cannot be implemented. In the case of a oil-fueled power plant, the Commons (atmosphere, rivers and sea) are used and filled up to generate wealth in favor of the plant owner, without any additional advantage to the other "share-holders" of the Commons. The latter pay for the electricity (or may have never used electricity in their life) without receiving any dividends from their "share" of environment that is used to run the plant.

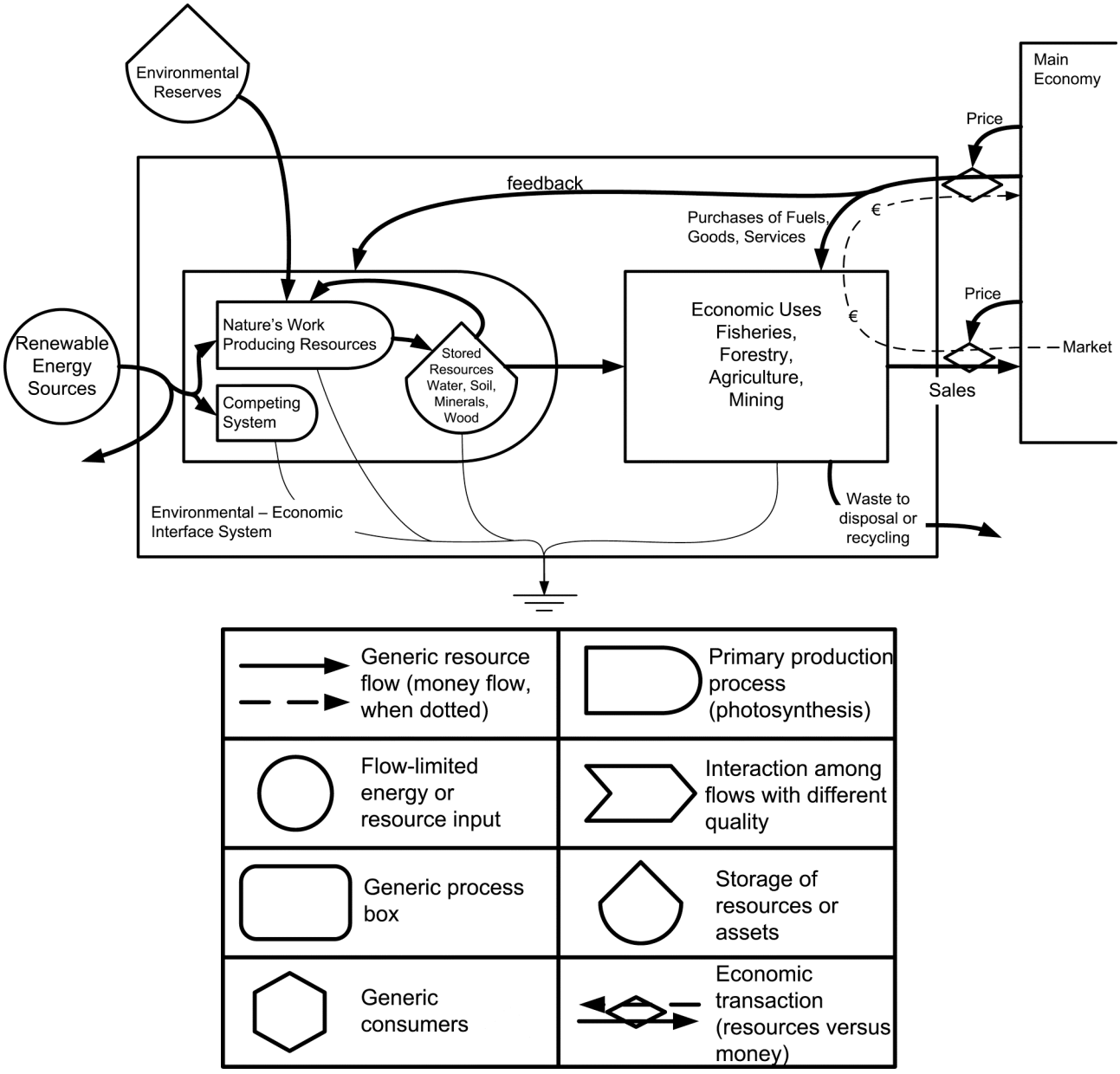


Figure 3. (a) Systems diagram of an economic systems within the framework of biosphere activity, showing supporting flows of resources and the reinforcing feedback from higher to lower levels of the hierarchy (Odum, 1996); (b) Legend of systems symbols used in Figure 3-a (Odum, 1996).

Barnes (2001) calculated as an example the potential dividends from the use of a selection of common resources in the USA such as the sky for dilution of pollutants and broadcasting. He also included in the accounting some "new" Commons, that were not considered earlier as economic resources, due to the fact that their scarcity is a recent event (e.g. societal assets, biodiversity, quietude, and financial liquidity). These new resources are most often an important basis for business; just think of liquidity, i.e. the possibility to sell stocks guaranteed by the existence and

operating of a Stock Market infrastructure regulated by the Law and by public institutions (which also are a new category of Commons themselves). According to Barnes, liquidity adds up to 30% of total value of a company, which means that the company benefits from the existence of common infrastructures and controls. Barnes maintains that the wealth generated by the use of common resources (flows and stocks of resources and infrastructures) should be accompanied by a return of wealth to all the "stakeholders", i.e. the large number of owners by birth rights. He foresees a "cap and trade" system strengthened by the distribution of dividends to the stakeholders or to their representatives. Such dividends could be converted into feedback actions to increase well-being (education, health services, retirement) or to further preserve and reinforce the resource basis exploited. The exploitation of the Commons would become more expensive for the production and business sectors, thus pushing towards wiser use and increased efficiency, while the distribution of dividends would make the residual exploitation more equitable and the stakeholders more aware of the need for preserving their shared "property". For example, when a company sells "made in Italy" products abroad, they also sell a share of the "image" of the country that belongs to every citizen, and that needs reinforcing feedback and reward (proper use of dividends).

Similarly to the Authors of the Millennium Ecosystem Assessment, Barnes faces the problem of how assigning the "right" value – if any – or at least an operational one to each flow or stock, by relying on something different than just human preferences (the market value). Although the idea of rewarding all stakeholders by returning them a fraction of the wealth created on their ownership is certainly fascinating and in principle applicable within the current free market system (as Barnes claims), its application is made in practice uneasy by the lack of a standard method for assigning value to each resource flow or stock. Such a method should be scientifically sound, applicable to all kinds of flows and stocks, independent of human preferences, and finally related to sustainability issues and environmental integrity (so that its application would improve the overall stability of the biosphere). Barnes refers to the need for a new market operating system that he names "Capitalism 3.0", the introduction of which is foreseen in the years to come.

6. Emergy-based evaluation of selected uses of resources.

The complex questions concerning the fit of humanity in the biosphere require that we look at things from a different perspective. Until the beginning of the industrialization, the emergies released by humans were small, compared with the renewable driving emergy. Instead, now-a-days human societies release about three times the emergy in slow-renewable and non-renewable

resources than flows into the biosphere from renewable sources. How best to fit humans and environment together? Decisions at the scale of biosphere and society require a valuation system free of human bias. It is not surprising that development of resources, exploitation of global fisheries and forests continue unimpeded when evaluated using economic value systems based on willingness-to-pay. Neoclassical economic valuation cannot overcome the fact that its main underlying principle is that value stems from utilization by humans and utility is measured in terms of benefit to human being only.

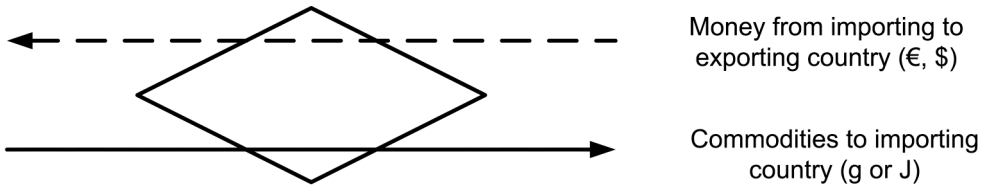
The following sections discuss selected applications of the emergy evaluation method, in order to provide details of the potentiality of the approach for sustainable resource management policies.

6.1 Emergy and equitable trade

It is nothing new that very few wealthy countries have access to (and actually use) the largest share of the world energy and material resources. The generation of environmental and social instability in several areas of the planet can be discussed in relation to the existence of such an imbalance. Conventional economic approaches quantify traded flows in terms of the amounts of goods traded and the money paid for them, once again without any quality assessment of the traded resources. The economic assessment of trade very often only focuses on money balance and does not take into proper account the real quality of (= what it takes to make) the traded resources as well as the related environmental problems, both from the point of view of the depletion of resources and of the pollution generated in the exporting country. Resources are very often mined and partially processed in the exporting country, then refined and used in the importing developed countries. The price of exported resources is very often inadequate to compensate for the depletion of local storages and the environmental burden generated by resource extraction and primary processing. Instead, resources drive significant economic and environmental benefits in technologically and economically developed countries.

The unbalance of resource trade among countries is of paramount importance to environmental and political stability, as clearly pointed out by Odum (1994b): "*Trade and projects that unbalance local economies [...] leave major sectors of the world's population in poverty, essentially outside the world economy. This pattern wastes resources into luxury and excess of the developed countries, diverting resources that used to go directly to population support (without payments). This pattern is not sustainable, does not maximize world wealth and emergy, does not reinforce world production, and will not last. These patterns will become discredited as world opinion changes, as revolutions occur, and worldwide resource depletion soon cuts off the largesse of the overdeveloped countries*."

Odum (1996) and Brown (2003) clearly identified the "advantage to the buyer" in the relations between industrialized countries and countries the economies of which are mainly based on exports of primary resources. This happens in spite of an apparent balance of money flows between trading countries (economic "terms of trade"). The situation appears even worse when the environmental burden associated to the traded resources is also taken into account and its geographical distribution is carefully investigated. It clearly appears that environmental and development problems cannot be solved by "free market" economy alone. The latter lacks the conceptual framework and the scientific tools needed to deal with the complexity of self-organizing systems, which operate on multiple scales and hierarchical levels. An emergy-based alternative definition of "terms of trade" can be provided whereby the emergy associated to the traded resource is compared to the emergy associated to the money received (Figure 4). By means of such a procedure, each traded product is multiplied by a suitable emergy intensity factor (transformity, seJ/J, or specific emergy, seJ/g), so that the emergy released for its production is calculated. The total emergy associated to the money paid for is then calculated by multiplying such a money flow by the emergy supporting a unit of GDP in the importing country, in so determining the total emergy that can be purchased in that country thanks to the money received. The differences between the economic and emergybased "terms of trade" accounting procedures are discussed in detail by Ulgiati and Cialani (2005), who maintain, building on Odum's emergy method, that the fairness of trade and resource exchange among developed and developing countries is hardly expressed by monetary indicators as well as by the conventional terms of trade. This is because money value underestimates a large set of free environmental services and natural capital uses, which are embodied in the traded goods.



$$\text{Emergy benefit to buyer} = \frac{\text{Emergy of traded products}}{\text{Emergy of money paid}}$$

Figure 4. Definition of trade in emergy terms (Odum, 1996).

6.2 Emergy and Environmental Taxation schemes (Envitax)

Bimonte and Ulgiati (2002) pointed out the existence of a "new scarcity", i.e. the increasing unavailability of important components of the life support system. The ability of the environment to

act as both a source of primary resources and as a sink for waste is not unlimited as it was in the past. If resource exploitation is carried out without any concern about its consequences on environmental integrity, degraded ecosystems become increasingly unable to provide basic ecological services (water cycling, photosynthesis, support to biodiversity, among others) and resources (wood, food, fresh water). As a consequence, these Authors (*op cit*) suggested a taxation tool based on Odum's emergy method, pointing out that, in general, environmental policies and taxation schemes only focus on a particular goal and do not take a general and global view of the environment's contribution. For example, the aim of the carbon tax is to reduce carbon dioxide emissions and prevent global warming, although atmospheric temperature is not the only parameter that requires control or feedback from the economic system. The integrity of the environment as a whole is of fundamental importance and taxation schemes or financial instruments must evolve in line with these objectives. According to Bimonte and Ulgiati (2002), the emergy approach offers a way to look at the quality of a production process, namely at its ability to reinforce the productive basis and avoid the waste of resources. Bimonte and Ulgiati also point out that environmental integrity and at the same time the reinforcement of the productive basis cannot be obtained by simply restricting the use of a given resource. As clearly underlined by Odum (1996): "*whereas energy conservation in the sense of increasing efficiency of use has net benefits, an economy that conserves in the sense of restricting fuel use tends to reduce … its ability to compete economically. Taxing fuels is sometimes offered as an incentive for energy conservation, but reducing fuel has a negative amplifier effect on the economy that may be greater than the increases in efficiency. If the tax reduces luxury and waste, the effect is beneficial*". To be effective towards environmental integrity, a taxation policy should therefore focus on the quality of production and use processes, i.e. the quality of resources used and the performance of the process as a whole, not just on the use of a single resource or the respect of a single parameter. Bimonte and Ulgiati therefore suggest a taxation scheme based on the Emergy Sustainability Index, ESI (Ulgiati and Brown, 1998), an aggregated measure that takes into account both economic advantages (return on emergy investment, measured by an Emergy Yield Ratio, EYR) and environmental loading (measured by an Environmental Loading Ratio, ELR). The ESI (calculated as the ratio of the EYR to ELR) is sensitive to both resource alternatives "renewable, non-renewable" and "local, imported". Its inverse tends to zero the more a process is sustainable and could be used to develop an environmental taxation strategy where taxes are proportional to a decreasing value of the index. Such a tax would be a way to penalize processes which use less environmentally sound technologies and less renewable resources. Of course, the inverse would be true for environmental incentives. According to the Authors, the Envitax scheme also suggests using the tax revenues to

restore the natural capital stressed by the human activity. If the environment is considered a fund instead of a stock, and if there is agreement that such a fund should remain unchanged by restoring its ability to sustain a certain process, using Envitax revenues to restore the natural capital would have multiple effects: a) slow down the appropriation and depreciation of the fund, b) restore the fund at the expenses of the polluters, c) implement an environmental policy based on both a comprehensive and global evaluation of biosphere work and the environmental quality of each input.

6.3 Environmental debt

An interesting point of view, rich with development and application perspectives, is also provided by the concept of emergy-based environmental debt accounting, developed by Campbell (2005). This author defines the concept of environmental liability and provides the conceptual basis for its operation in the form of an energy systems model. The concept of environmental debt is based on the recognition that economies receive work contributions from the environment (services, resources, natural capital depleted or degraded, etc.) without providing sufficient payment in the form of reinforcing feedback. In order to solve such an important lack of proper accounting of the environmental services and capital, a Double Entry Book-keeping was suggested, similar to the traditional methods used in financial accounting, where emergy is used to document environmental liabilities and to construct a balance sheet that accounts for all economic and environmental work contributions to economic production. According to Campbell, ‘‘*once all empower credits and debits in the environmental and economic system are known, recorded and analyzed, the political process can be used to address questions of the appropriate debt load to be carried by society, and the schedule for repaying existing debts*’’. Campbell’s environmental debt concept is therefore very close and complementary to Barnes’ dividends approach and deserves further study and implementation.

The cases presented (trade, envitax, environmental debt) share two common characteristics:

a) they include in the assessment the donor-side point of view and patterns of quality assessment. Resources (flows and storages) are not valued based on human preferences, but are valued according to their demand for environmental support over time and space. The larger the time and spatial scales involved, the longer the turnover time and the more difficult is to replace a resource when used up. Some resources less “priced” by market dynamics or not marketed at all, might well appear crucial and very valuable based on a biosphere system of value.

b) For all of them the concept of feedback reinforcement is crucial, be it a fair reward for a traded resource, the restoration of natural capital by reinvesting environmental taxation revenues, or finally a schedule for repaying the environmental debts. Again, the appropriate intensity of such a feedback is something that is hardly evaluated or not considered at all within the conventional market dynamics.

The use of the Emergy evaluation method allows the identification of a "biosphere value" for resources and commodities that could profitably complement monetary evaluations. As a consequence, the efforts of ecological economists and concerned policy makers towards a proper management of natural capital and ecosystem services would be reinforced by the new framework available.

7. Summary and concluding remarks

Natural capital, the common heritage that we received from past Nature's work and the integrity of which was preserved by the careful use of the previous generations, is now at risk. Its exploitation in support of unsustainable economic growth driven by global markets and business-as-usual patterns generates a fragile wealth in favor of a minority of the world population. Authoritative studies warn about the crucial role of natural capital and ecosystem services that must be preserved for the well being of the whole planet and passed to the next generations. Regulatory policies and taxation schemes have been suggested and the debate about the most convenient strategies is still in progress. Environmental and social aspects are strictly intertwined so that decision making is even more difficult and choices questionable, calling for local communities and new values come into play. Evaluation of natural capital cannot only rely on financial tools based on human preferences and fluctuating market dynamics. New strategies need more comprehensive quantification of natural capital and ecosystems services, as well as involvement of citizens in their management, also through assignment of dividends based on shared ownership concepts. This would allow full awareness of the importance of shared resources (natural capital and environmental services) and can become the basis of informed participatory strategies for appropriate, equitable and sustainable management of the common resources.

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