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Ecological Integrity as an Emergent Global Public Good

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INTRODUCTION

Globalization has meant opening markets worldwide to free trade in goods and services. Cross-border transactions also involve investment, travel, communication, entertainment, insurance, migration and more. However, not all interactions among economic agents go through the market and deal with goods and services. As market interactions increase globally, unintended non-market interactions among economic agents, externalities in economic parlance, increase *pari passu.* These externalities can be positive or negative or both according to the issues. The goods and services involved in these externalities may be intangible and are then more of the nature of conditions, such as enhanced security. For example, the quasi-universal availability of banking machines improves travel security around the planet but, at the same time, increases the level of global travel, which may have negative environmental effects. Avian flu, a negative externality (it is not transmitted through market transactions), has worldwide relevance; so has the quasi-eradication of smallpox, a positive externality. Economic development increases opportunities while accelerating the burning of fossil fuels and the build-up of the concentration of greenhouse gases in the atmosphere. Many risks increase with globalization. For example, the decline of biodiversity worldwide leaves us more exposed to diseases, whether affecting plants, animals or humans. Security issues, whether financial or environmental health- or conflict-related, are global but cannot be resolved through markets or through markets alone. Neither the costs nor the benefits of externalities are reflected in the prices or profits of market transactions. The speed at which these non-market interactions occur has also greatly increased. We need policies and non-market institutions to complement the markets and manage these externalities issues in a timely fashion through preference-revealing and political bargaining not only for efficiency but also for fairness. If the scale of these externalities can be managed, those affected most by them should have a say in their regulation and provision according to the principle of subsidiarity or of fiscal equivalence. The principle of subsidiarity means that regulations and actions should be implemented at the lowest level of administration possible, presumably closest to the citizens concerned, in other words the stakeholders. The principle of fiscal equivalence says that those who benefit from the externalities should be the ones who contribute the resources needed for their management (Kaul and Mendoza, 2003). Numerous international institutions have been created to handle externalities, including heightened risks. Many more institutions are on their way.

A public good shares many economic properties with positive externalities, but a public good is typically recognized as such and policies are adopted to encourage a deliberate level of provision. The question investigated in this chapter is whether ecological integrity, as an emergent property of an ecosystem, is a public good and, in the affirmative, to what extent policies can influence its provision. If ecological integrity is a public good, and one that has been in decline in critical ecosystems around the world, then deliberate mechanisms, cooperative or incentive-compatible, are required to provide the conditions necessary for its protection and restoration. Some public goods are intentionally created to enhance the opportunities and reduce the risks associated with globalization. These include systems of communication and finance and governance institutions, systems of negotiation and decision-making deliberately created to regulate and enhance the flow of market goods and services worldwide that, through economic, social and political positive feedback, further increase the global flow of market goods and services. Examples are international and non-governmental organizations such as the World Trade Organization (WTO), the International Monetary Fund (IMF), the Intergovernmental Panel on Climate Change (IPCC) and the International Union for the Conservation of Nature (IUCN). These institutions are often set up for the purpose of managing and allocating global public goods (and bads), whether or not their leaders and participants see their mission in those terms. Many of them are designed to address the harms associated with globalization. This is particularly true of global environmental institutions whose mission is to protect and restore public goods associated with the global commons, the Earth's oceans, atmosphere and hydrological cycle, whose conditions determine the habitability of the planet. For the past 15 years, the Global Ecological Integrity Group (GEIG) has been grappling with the question of the relationship between ecological integrity and human habitability (see, for example, Crabbé, 2000; McMichael and Kovats, 2000; Miller and Ehnes, 2000; Pimentel et al, 2000).

Ecological integrity is an ecosystem property, in other words a property of the entire ecosystem or of the system structure of ecosystem relations which is not shared by its components. Ecological integrity is an emergent property of a self-organizing ecosystem, in other words a property that spontaneously connects its macro-properties with its micro-properties. For example, the resilience of the forest as a macro-property may be connected with the age composition of the forest component tree species, a micro-property.

The questions investigated in this chapter are: whether ecological integrity, as an emergent property of a complex system, should be considered a global public good; how scientific knowledge of the state of ecosystem integrity affects how and how much it is valued; and whether being a global public good enhances the protection of ecological integrity or whether it places it further at risk. The answer to the final question depends on the relationship between the goods (private or public) provided by ecosystem components (for example water, timber or whales) and the ones provided by the ecosystem services. If the benefits provided by the whole (ecological integrity and other emergent properties and associated services) exceed the benefits of the parts (natural resource products), ecological integrity has a better chance of remaining intact (of being provided at a sufficient level), unless the benefits provided by the parts are private ones while the benefits of the whole are public and not supported economically and politically by policy. Those interested in protecting and restoring integrity can learn from how some global public goods are effectively provided by institutions and policies while others are not. How does the fact that a global public good is also an emergent property of systems have an impact on its provisioning? What policies need to be put in place to protect and sustain ecological integrity?

Ecological Integrity as an Emergent Property of a Complex System and as a Global Public Good

Ecosystems are complex dynamic systems whose component variables interact non-linearly across a range of spatio-temporal scales and which are subject to stochastic disturbances such as climate variability (Chee, 2004). Humans benefit from ecosystems through the latter's goods and services. Ecological goods and services are the conditions (intangible goods and services such as resilience, health, ecological integrity and biodiversity) and processes through which natural ecosystems and the species that compose them sustain and fulfil human life (Daily, 1997). These conditions and processes encompass the delivery, provision, production, protection and maintenance of these goods and services (Daily, 1997). They impact the provision of inputs to production processes and human welfare either directly or indirectly through the regulation of natural processes (Nunes and van den Bergh, 2001). Ecological goods and services are economically valued by their total economic value, i.e. the sum of their use value (direct benefits), non-use value (indirect benefits) and existence value. Because ecosystem goods and services may be interdependent, economic valuation may lead to sub-additivity (leading to double counting by counting essentially the same service twice) or super-additivity (as an outcome of services' and processes' interaction, a form of emergent value, a value assigned to the system structure, independently of the value of its components and their addition) (Chee, 2004).

Ecological integrity is defined here, following Karr and Dudley (1981), as 'the capacity of an ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of similar, undisturbed ecosystems in the region' (cited in Carignan and Villard, 2002). Ecological integrity, like resilience and, sometimes, biodiversity, is a concept that applies to an entire ecosystem; it is, therefore, a system property. It is a difficult abstract concept, still little understood (Nunes and van den Bergh, 2001). This system property is called 'emergent' if it relates spontaneously the system components (their micro-properties) to the system macro-properties. It is an abstract concept that can be associated with a wide range of benefits to society. For example, a leaf from a tree may not have the property of ecological integrity, while an entire forest can. This does not mean that the leaf cannot have some form of integrity (without which it is no longer a leaf), but it cannot have ecological integrity unless one characterizes a leaf as an ecosystem in its own right (i.e. including its insect population and its predators).[1] As another example, resilience, as a macro-property of an ecosystem, say a forest, is the outcome of the arrangements of and interactions among the micro-properties of its ecosystem components, say trees, shrubs, fauna and so forth. Resilience is the capacity of a system to maintain its characteristic patterns, structures, function and rates of processes despite perturbations (Carignan and Villard, 2002).

Biodiversity, on the other hand, can be defined as a property of the component species of an ecosystem, for example species richness or the diversity function, or by a property of the ecosystem, for example species evenness, the distribution of species, which is an emergent property. Heal calls biodiversity a commodity because it provides utility directly (Heal, 2004).[2] Biodiversity provides or enhances ecosystem productivity, insurance, knowledge and ecosystem services. Brock's measure of biodiversity as 'the value of characteristics or services that an ecosystem provides or enhances when managed optimally' is an emergent property as well (Brock and Xepapadeas, 2003). If resilience is positively correlated with biodiversity, valuing biodiversity is a proxy for valuing resilience. If biodiversity is affected by an environmental driver, it is on the environmental driver one should focus attention, in particular if the driver is subject to management, for example in the case of water (Knowler, 2007). Biodiversity value arises from the total of values arising from species and genetic diversity, values associated with natural areas and landscape diversity, benefits from ecosystem functions, and non-use values stemming from biodiversity.

An emergent property of a system often, but not always, has the economic properties of a public good if it is considered valuable by economic agents.[3] A forest, for example, may have greater economic value than the sum of the values of its components if it is a resilient ecosystem endowed with many interdependent ecological services (timber, wildlife, water and nutrient storage, etc)[4] (Chee, 2004). Often this greater economic value will be apparent to society as a whole, but not to an individual who is unable to appropriate it, in other words to exclude others from its benefits (see Costanza et al, 1997; UNEP, 2005); moreover, to have the property of 'pure' public good, the emergent property must be 'non-rival' in consumption, thus my enjoyment or appreciation of the integrity of an ecosystem and its associated services should not diminish their availability to others at zero cost, in other words it is not exhaustible. Some ecosystem services, such as the carbon sequestration of a forest, are neither excludable nor exhaustible. I am unable to exclude anybody from the benefits of carbon sequestration; the benefit I derive from carbon sequestration does not impinge upon – is non-rival with – its consumption by others. This is precisely the definition of a pure public good: a good or service which is neither excludable nor exhaustible. Since this property is available to everybody on the planet and all generations, one can therefore rightly speak of it as a global public good (Kaul et al, 1999). On the other hand, some ecological functions of the forest, such as timber provision, are excludable and rival in consumption. Ecological integrity is, therefore, a macro-combination of inter-related public and private ecological goods and services, many of which are themselves public goods that interact with other ecosystems, providing what economists call externalities if these interactions affect human beings positively or negatively. Ecological integrity is, therefore, a public good. It is the (super-additive) compact of private and public ecological goods and services. To put it in ethical terms, ecological integrity has a good of its own, which is not reducible to the sum of the benefits derived from its ecological goods and services.[5] The features of a public good are largely institutionally determined because these, non-exclusivity, for example, depend upon specific definitions and allocations of property rights and the perceived value and availability of the good or service. For example, elementary school education is not rival in consumption when it is available to all but becomes rival when it is not (Kaul and Mendoza, 2003).

Since an individual will be expected to underestimate the value of a public good, pure public goods are not good candidates for production or supply by private firms or individuals, who are unable to charge a price for them. In the case of global public goods, a similar argument may be made for countries as economic actors, as well as for private firms or individuals. Since the private sector (or collection of sovereignties) may underestimate the social value of (global) pure public goods, the former will produce or supply too little of the good for the benefit of (global) society. Therefore (global) pure public goods ought to be supplied by governments (or international institutions) that have the ability to charge taxes to pay for the provision of the public good, for example to pay for conservation measures and other measures to protect and restore ecological integrity (Davies and Slivinski, 2005). International institutions do not have taxation power, however. Therefore, individual countries acting in consort with others in international agreements will necessarily be responsible for the provision of environmental public goods, most significantly ecological integrity.

This is not the whole story, though, because the level of provision of public goods depends upon people's preferences for many other public goods, such as security, public health and financial stability, and because, in democratic societies, the level of provision of a public good depends upon political bargaining. This applies in the international sphere as well.

SCIENTIFIC ASSESSMENT OF ECOLOGICAL INTEGRITY

Ecological integrity, in order to have economic value, must be known to exist in an ecosystem and, therefore, must be scientifically[6] assessed. The resulting scientific information, furthermore, must be made public. In other words, ecological integrity depends upon knowledge generation that is also endowed with public good features.

Considering how information about ecological integrity is also a public good, we can use the same logic to address how such information can best be provided. Information about ecological integrity may be generated by public authorities (for example the government) or by private ones (for example private universities or consulting firms). A government may contract out the scientific studies or produce them on its own; it may decide how much information to make public and to whom this information will be released and at what price. If the information is provided entirely privately, the question arises about whether this activity should be regulated (Davies and Slivinski, 2005).

Meteorological information is an example of scientific information that has private value: the government providing meteorological information is able to exclude people from accessing it by charging a price for it. However, the information remains inexhaustible: the information provided to my neighbour does not decrease the information available to me. Once the raw meteorological information is massaged into a service designed for a specific customer or category of customers (for example farmers), it remains inexhaustible but becomes excludable. Some people have argued that raw meteorological information should be nearly freely available to all because no private providers would be able to charge a price which allows them to recoup the large cost of production of meteorological information (large supercomputers, etc); the only price that could be charged would be the additional cost of dissemination of the information to an additional individual (for example paying for a hard copy of the forecast). Special groups of customers or firms provided with targeted information can be charged the price of massaging the information, since targeted information would not be worth producing if customers were not willing to pay for it (Davies and Slivinski, 2005). A group of customers or firms could derive a private benefit from knowing the state of ecological integrity of an ecosystem. This could take the form of existence value for individuals or of insurance for firms. Ecological integrity is, in some cases, a proxy for biodiversity or, more

precisely, for the presence of an indicator species whose benefits can be appropriated. Organizations whose members value certain species, or those who harvest from the wild, are interested in protecting the ecological integrity that sustains certain habitats. There is at least one example of a private business – ICValue Inc., founded by Orie Loucks, an ecologist associated with the Global Ecological Integrity Project – that sells information to environmentally responsible individual investors and green investment firms about the impacts of corporate practices on ecosystem integrity (see www.icvalue.com/).

Scientific information, including information about ecological integrity, can be made available in the form of raw data, or the information can be processed and targeted for interpretation and use by specific customers. The provision of raw data is often a basic service provided by the government free of charge (except for the cost of dissemination to an additional customer), while the provision of processed information requires more specialized, value-added services for which a charge corresponding to the customer willingness to pay can be levied. Typically, the provision of public goods, such as environmental information, by private agents is insufficient because it is subject to a market failure: the benefits of the good or service cannot be captured by adding up the quantities of the good or service consumed and selecting the price to which this aggregate quantity corresponds on a market demand curve for the good or service in question. This is why pure public goods are provided by governments according to citizens' preferences and political bargaining. The provision of targeted information by a private company may lead to a natural monopoly if the unit cost of the information provided decreases with the amount of information provided.[7] Therefore, the private unregulated firm would be able to charge an inordinately high price to its customer (Davies and Slivinski, 2005).

Information about ecological integrity is valuable because it reduces collective risks, in other words it has insurance value. Knowing the state of ecological integrity of a given ecosystem, or for global ecological integrity as a whole, allows ecosystem users or governments to take appropriate actions which could protect or restore ecological integrity. Knowledge about the loss of integrity enables forecasts and the issuance of warnings about degraded future states of the ecosystem. These warnings are useful to specific users, who benefit from the ecosystem goods and services sustained by ecological integrity (Davies and Slivinski, 2005).

If raw data relevant for assessing ecological integrity is an intermediate good that is used in the production of targeted information, a price should be charged for the raw information corresponding to its opportunity cost. The opportunity cost is the total cost of producing the raw information if there is a single user. If there are several, the opportunity cost is the cost of dissemination since nobody can effectively be excluded from the information (Davies and Slivinski, 2005).

The consumption of public goods may also generate externalities, in other words may confer benefits or costs to other individuals. For example, knowing that the ecological integrity of an ecosystem has been degraded may induce people to move to another ecosystem, thereby increasing the value of the latter's services. These are called pecuniary externalities and do not affect the argument, since increasing the gains of producers decreases the welfare of consumers, each cancelling the other.

On the other hand, if knowing that an ecosystem has been degraded leads to me having to decrease my extraction activities from an ecosystem, this reduced activity benefits others, though the benefits are not necessarily equal to the cost I incurred by reducing my extractive activity. These are benefits that are not automatically compensated for by my losses. These are truly (technological) externalities. If a public good confers positive externalities, the provider may charge less for the public good or improve its quality to encourage its dissemination (Davies and Slivinski, 2005).

Raw data and processed information are not independent. The more data there is, the more valuable and the cheaper the targeted information because the latter becomes more reliable. In turn, the higher the demand for targeted information, the more raw data will be supplied since the latter has become more valuable. Targeted information does not have to be provided by private firms necessarily, even if they are more efficient than public firms in doing so, because there may exist economies of scope in providing jointly raw and processed information (it may be cheaper to do so) since the inputs are common to both types of firms (Davies and Slivinski, 2005).

The provision of information about ecological integrity may create problems related to the asymmetry of information. A farmer, having been informed by some government programme that his fields provide socially valuable ecosystem services, may have the incentive to exaggerate the cost of his unmonitored conservation measures (or 'best management practices') in order to obtain government compensation. This is called a moral hazard problem: the farmer has an incentive to distort the information he alone possesses. Moreover, if only farmers whose fields have been environmentally degraded are eligible for restoration subsidies, incentives may be created to allow ones' fields to degrade. This is called an adverse selection problem. Only the worse risks participate in the government programme.

Governments could provide forecasts about the state of ecological integrity of an ecosystem. If this forecast depends upon information privately owned by an individual, this individual may have an incentive not to reveal the information that the ecosystem is in poor state because a prospective buyer may attach much importance to ecological integrity (for example Nature Conservancy). If the information is inexpensive to acquire, only ecosystems with substantial ecological integrity will be acquired if the seller is not concerned about reputation. If the information is expensive to acquire, the buyer will take his chance and buy the available ecosystems, discarding the bad ones if he believes ecological integrity is a dominant feature. If he believes the reverse, no ecosystem will change hands. If reputation matters, the seller has a stronger incentive to hide the truth. If

information is expensive to acquire, he may lie about the state of ecological integrity and the buyer may be unable to identify the state of ecological integrity (Stoneham, 2003; Sheriff and Osgood, 2007).

DOES THE QUALITY OF GLOBAL PUBLIC GOOD ENHANCE ECOLOGICAL INTEGRITY?

One problem with ecological integrity is that, though it has clear social value, there exists no current accepted means to measure it and express it, resulting in its perceived value being effectively rather low (Carignan and Villard, 2002; Antrobus and Law, 2005). One way to express the importance of ecosystems whose integrity remains largely intact is to protect them as special areas by granting them status as parks, usually though not always public. In these cases, their economic value is often enhanced by tourism. The emergence and growth of the ecotourism sector is one way that the economic value of ecosystem integrity has been able to be made manifest. Since biodiversity is often (although not always) positively correlated with ecological integrity, another approach to valuing integrity is to link it to efforts to value biological diversity and associated goods and services.

Ecological integrity provides at the same time ecosystem services, often public and distant, and natural resource products, usually private and local. It requires trade-offs between socially relevant but poorly known values and local ones, more easily appropriated, which can be better measured. The social value of ecological integrity may be best assessed scientifically and communicated both to the beneficiaries, which may be distant, even global, and locally to those most dependent on ecosystems to provide the resources for their livelihoods. The local values can then be enhanced by a levy (for example on ecotourism), which stands as a proxy for the social value of ecological integrity. Local incentives to protect ecological integrity would then amount to compensating local communities for their conservation efforts (Perrings and Gadgil, 2003). This requires establishing local property rights, whether private or communal or some mix of the two.

If a government would like private landowners to take measures to protect ecological integrity, it may subsidize them to do so. This subsidy may turn out to be expensive, because a private landowner might in any case undertake the measures without the subsidy or with a much lower one than the one being offered. It is therefore important, for a government that has a limited budget to devote to ecological integrity, to find out how much a landowner would be willing to devote to ecological integrity protection. A simple contingent valuation exercise will not do, since the landowner may have an incentive to lie about the true cost of the conservation measure on his land in the hope, for example, of receiving a subsidy which exceeds the cost of the measure (Chee, 2004). It is, therefore, important to design mechanisms such as certain types of auctions in which there is an incentive for the landowner not to lie. The landowners who bid the lowest price for the measure as compared with its environmental benefit would get the government subsidy for the environmental measure to be undertaken. Moreover, since shoring up ecological integrity requires a minimal area of land (for example a biosphere reserve), the mechanism requires that there be benefits in aggregation, in other words that neighbouring landowners have an incentive to bid the lowest price for the measure in such a way that it enjoys sufficient scale to protect ecological integrity. This is a recent subject of environmental economic research on institutional mechanisms (called reverse auctions) which lead private property owners to implement public goods on their land at minimum cost for the public purse (Stoneham, 2003). These institutional mechanisms can be tested in the laboratory and are the subject area of a field called experimental economics. Examples of application of this methodology can be found in the US in the Conestoga watershed in Pennsylvania for phosphorus; in Australia in the BushTender and EcoTender programmes in the state of Victoria for various environmental objectives, including biodiversity protection; and in Canada in the Pilot Emission Removals, Reductions and Learnings (PERRL) programme for greenhouse gas emission reduction (DAA Stratégies and CIRANO, 2007).

CONCLUSION

The social value of ecological integrity may be far higher than the value (or sum of values) of its components, but the only way to establish it is to assess it through scientific research and ensure that the information provided is targeted mainly to local users of the ecosystem, even if global public goods must be provided internationally by the principle of subsidiarity or fiscal equivalence. Yes, externalities, including increased risks, go hand-in-hand with globalization, but so does institutional cooperation, which determines ultimately which good is public and how much of it must be provided through preference-revealing and political bargaining in order to insure against these new risks. Their cost can be kept low by designing institutional mechanisms which are truth-revealing and provide incentives to protect ecological integrity at the scale required.

In conclusion, we have looked at the economic implications of ecological integrity as an emergent property of ecosystems, a macro-property fundamentally responsible for the continued provision of a number of critically important ecosystem services. Ecological integrity clearly meets the criteria of a global public good. And being a global public good, it will only be protected and restored through the deliberate development of global institutional mechanisms to create economic value through information and cost-effective compensation for local conservation. These will have the most likelihood of success if they are designed with full understanding of the dynamics of both emergent properties and global public goods within the appropriate institutional context.

NOTES

1 As is often the case in the systems approach, an emergent property depends very much on how the system considered is being defined.
2 See Brock and Xepapadeas (2003) for an overview.
3 All emergent properties are not necessarily global public goods, however. For example, a Pareto distribution is an emergent property of a whole slate of social system phenomena, but it is not a public good; it does not per se provide any benefit. Some global public goods, such as national security, are not necessarily emergent properties of a system, but are more like membranes, component parts of a system that function in biological systems to mediate relations with other systems and the external environment.
4 The pure theory of public goods determines that their allocation is optimal when the sum of the marginal willingness to pay for one more unit of the good equals the marginal cost of producing one more unit of the good. This is known as the Samuelson condition (Chee, 2004).
5 Some ecosystems may produce public bads as well, such as when the ecosystem is a hotbed of parasites such as vector-borne malaria (Perrings and Gadgil, 2003).
6 We use the word science broadly to encompass social sciences as well as soft system approaches.
7 This will occur if the production of targeted scientific information is capital-intensive.

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PART II

ECOLOGICAL INTEGRITY AND BIOLOGICAL INTEGRITY: THE INTERFACE